



South Africa Clay Brick Sector Energy Efficiency Guidelines



www.claybrick.org/energy-efficiency-guidelines



This study was undertaken by Clay Brick Association - representing the brick makers that participated and contributed to the development of the guidelines, and who should ultimately take ownership of the guidelines.

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Foreword

In the context of rising energy prices and governmental drivers to address climate change, energy efficiency is an imperative for industry. By reducing energy use and addressing the demand side of the equation, it is possible to reduce energy bills, make the energy system more sustainable, and have a positive impact on greenhouse gas emissions.

As a key player within the South African industrial landscape, the brick sector can show real leadership in driving the adoption of energy efficiency best practices.

Through the Energy Efficient Clay Brick Project (EECB), funded by the Swiss Agency for Development and Cooperation (SDC), Swisscontact has been working with the clay brick sector in South Africa since 2009, with the aim of reducing energy use across the approximately 100 industrial clay brick manufacturing plants in South Africa. As part of the work, Swisscontact elected to develop an Energy Efficiency Guideline as a reference tool for operators in the industry. The guideline compares South Africa's brick sector energy performance with international benchmarks, and aims to develop a better understanding of thermal energy flow inside brick kilns and identify best practices and business cases to help the industry to deploy the necessary measures.

Many institutions and individuals have supported the development of these guidelines and we would like to acknowledge their contribution. They include our funding agency, SDC, the Clay Brick Association, a number of brick manufacturers, the Department of Energy, the Department of Environmental Affairs, the Carbon Trust, National Cleaner Production Centre (NCPC), and a number of local consultants, including John Offerman, Oliver Stotko, Moses Motaung and Chris Dickinson.

The EECB Project will continue to work with the sector to support the implementation of best practices and new technologies. We hope manufacturers and other stakeholders who work with them, find these guidelines and the accompanying thermal tool helpful, as they think about future energy efficiency deployments.

John Volstead, Project Manager
Energy Efficient Clay Bricks

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Executive Summary

The brick sector is a key player in the South African industrial sector. The 100 or so industrial brick companies in operation today 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. These guidelines set out the opportunities for the brick sector to reduce its energy intensity, i.e. the energy required per output of product (MJ/kg).

There are three types of benchmarks presented: (1) Site specific; (2) Sector; and (3) International Comparison. Setting targets to improve one's own performance is a great first step as it helps to focus internal thinking on energy efficiency and has the potential to make a huge impact on the reduction of energy use. Obtaining sector-wide data on production levels and total energy use 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. We have seen - for instance in the 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 (though a lower % of total

energy costs, given the high cost of electricity), a key finding of the project is the need for a deeper understanding of thermal energy use among both brick companies and the energy auditor community. Many of the sector energy efficiency audits undertaken to date have focused largely on electricity best practices. A thermal model has therefore been developed to help brick companies better understand where the heat energy is flowing in their plants, with the aim of restricting these losses. It also points to specific measures that can be adopted to reduce losses. Additionally, the NCPC has recently run training workshops around thermal energy reduction opportunities for brick managers.

The guidelines then point to some 75 best practice opportunities grouped into 10 areas. These include "Improving combustion efficiency" and "Reducing heat loss through kiln structure". Each best practice includes the cost of deployment, the savings expected and the simple paybacks likely to be achieved. The guidelines then take 10 of these best practices and provide very detailed business cases for them, which we hope will help brick manufacturers feel confident about implementing the measures.

The guidelines present the Energy Management Systems (EnMS) approach to energy efficiency, including discussion on ISO50001 and the training available to industry.

The EECB will be looking to demonstrate a number of these best practices in 2016 for completion by the end of 2016, with dissemination of the findings in 2017, including case studies, events and other support.



1. Introduction

1.1 Project Objectives

The project aims to develop guidelines that will help the South African brick sector to reduce its energy costs and become more energy efficient. Specifically, the guidelines would provide a deeper understanding of the international benchmarks of energy use, and assist fixed kiln sites to visualise their thermal energy flow and understand the best practices and business cases that could be relevant to them.

In order to achieve this, the project undertook a series of activities, analysis and sector engagements, including:

- Literature review of international best practices to assess the energy intensity of a range of brick kiln types (including clamps and fixed kilns) across key markets (China, India, Bangladesh and UK).
- Analysis of a number of audits at brick sites completed by the Private Sector Energy Efficiency Programme (PSEE) and the National Clean Production Centre (NCPC).
- Development of a thermal energy model to identify where losses are for fixed kiln manufacturers.
- Identification of the best practice opportunities for the industry across both thermal and electrical energy use that include indications of cost to deploy, as well as the savings achievable.
- A number of detailed business cases that show how best practice can be deployed, the maturity of the technology, more detailed cost analysis, and the barriers and risks involved with deployment.
- Presentation of an Energy Management (EnMS) approach and ISO 50 001, including training undertaken by NCPC.
- Workshops to source industry perspectives,

prioritise best practices and better understand the challenges faced.

1.1.1 Energy Efficient Clay Bricks (EECB) Programme

The Swisscontact-implemented EECB Project, funded by the Swiss Agency for Development and Cooperation, has been working actively with the clay brick sector across three dimensions:

- **Supply:** Encouraging energy efficiency among brick makers;
- **Demand:** Ensuring that specifiers and developers are fully cognisant of the environmental credentials of brick as a building product;
- **Enabling Environment:** Influencing government and other key stakeholders to provide opportune policies and conditions in which energy efficiency is supported, as well as collaborating with financial institutions seeking opportunities for the funding of energy efficiency measures.

1.1.2 The Importance and Challenges of Energy Efficiency

With rising energy costs for both electricity and fuels, and given that in the brick sector, energy can account for between 40% and 60% of production costs, energy efficiency represents a significant opportunity for cost reduction.

However, there are many barriers to deploying best practice energy efficiency measures, the following in particular:

1. **Knowledge of the opportunities:** Having a clear understanding of the various best

Importance of EECB

This project looks to address the supply side to ensure supply understands how it is performing versus international companies, as well as providing specific energy efficiency measures that can be implemented.

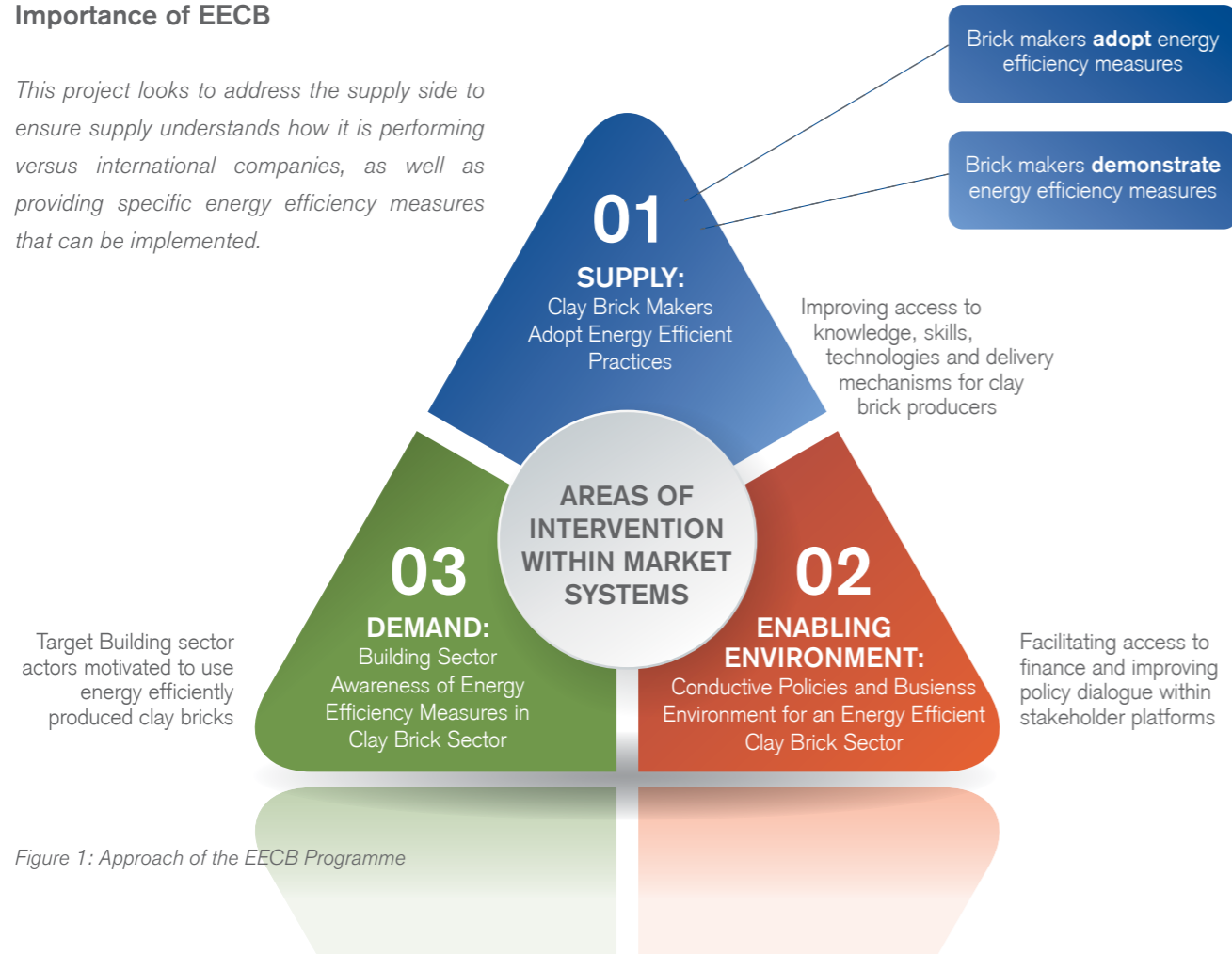


Figure 1: Approach of the EECB Programme

EECB Project Reminder



Figure 2: Project's structure and approach

practice measures that can be deployed, both technically and in terms of investment return; there are often complex considerations for process specific measures.

- 2. Energy Manager to focus on assessing these:** Ensuring that companies have the required personnel for whom energy efficiency is a key part of their role.
- 3. Finance to deploy them:** Financial resources to meet upfront costs; requires access to capital to be able pay for the best practice measure and convincing the Finance Director that this has material impact on the business.
- 4. Understanding of how to deploy:** Knowing exactly how to deploy the solution and having confidence in the suppliers and consultants who will ultimately design and deploy the solution.

ensure they are also supportive of the project and its conclusions.

- **Private Sector Energy Efficiency Programme (PSEE):** Important - works in partnership with business to provide advice and audits on energy efficiencies to small, medium and large companies.
- **National Cleaner Production Centre (NCPC):** Important - promotes the implementation of resource efficiency and cleaner production methodologies for industry. It also offers training on Energy Management (EnMS) approaches and on ISO50001.
- **Universities and Research Institutes:** Optional - since this is not innovation-focussed, this group is helpful but not critical.

1.2 Key Stakeholders

Critical to the success of the development of the guide is engagement with a number of key stakeholders, many of them already engaged with EECB at various levels within the EECB stakeholder grouping.

They will have different levels of input into the project, and include:

- **Swisscontact:** Critical - as the funder, through the EECB Project, for the development of the guidelines, and given the relationship to date with the trade association and others, Swisscontact involvement is crucial.
- **Clay Brick Association:** Critical - Representing around 100 brick makers as members of the association.
- **Brick Manufacturers:** Critical - provide sites for audit, provide access to data and provide ideas.
- **Equipment Suppliers:** Important - provides ideas, as well as being integral to the work programme described above.
- **Government:** Helpful - it is always useful to have a government department represented to

1.3 Activities Currently Undertaken by Other Organisations

There are activities taking place that are relevant to mention here, as they help to inform work on energy efficiency. These include:

- **Brick Sector Marketing:** The CBA, as part of its ongoing remit, conducts marketing on behalf of the industry to ensure the sector is well positioned with its customers and demonstrates benefits linked to:
 - o Quality;
 - o Price versus competing products (such as glass, stone and wood);
 - o Environmental credentials; and
 - o Aesthetics.
- **Site Audits:** The PSEE and the NCPC completed a number of brick sector audits with recommendations to the host companies on energy efficiency opportunities.
- **Training:** The NCPC conducted training to the brick sector on energy efficiency opportunities and EnMS approaches (see Section 6.6).

2. The South African Clay Brick Sector

2.1 Typical Clay Brick Production Methodology and Product Variations across the Sector

2.1.1 Clay Brick Basics

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.

2.1.2 Simple Drying and Firing Technology in South Africa

As mentioned above, it is commonplace in South Africa that the drying step be carried out in the open air. This is done for reasons of capital cost, simplicity and the firing method most commonly employed in South Africa, known as a clamp kiln. Clamp kilns are repeating structures built from unfired bricks surrounded by a thin casing of usually unsaleable fired product. Due to their nature, it is not possible to recover waste heat from clamp kilns for use in the drying process (see picture alongside of a clamp kiln). This generally results in clamp kiln producers being reliant on the weather for drying and consequently, their businesses can be severely affected by prolonged adverse weather conditions.

Clamp kilns themselves can also be negatively affected by inclement weather. They are essentially uncontrolled firing structures that once constructed and lit, are left at the mercy of the elements for firing of the bricks inside the kiln to occur. Energy for firing is commonly provided by pulverised coal known as duff, which is mixed into the body of the product during the milling and shaping process. At present, it is estimated that between 60% and 70% of the bricks made in South Africa are produced in clamp kilns. Clamp kilns are known to be very inefficient in their use of firing energy and they are also often criticised for high levels of atmospheric pollution.

Due to increases in coal costs, labour costs and pollution control legislation, there is mounting pressure on clamp kiln producers to convert their operations to different firing technologies. Indeed, it is no longer possible for a new clamp kiln operation

to obtain an operating licence (Mienie, 2014). Cumulatively, these factors have led to concerted efforts towards finding suitable alternative firing methods to clamp kilns in South Africa, but clamp producers collectively are reluctant to embrace change.



Figure 3: South African Clamp kiln

De Giovanetti & Volstedt (2013) suggested the reasons for the delays include a conservative mindset and an unwillingness to change, lack of access to finance and environmental red tape. Additionally, an often-overlooked factor is that clamp kilns can create a reducing atmosphere when firing, thus producing more aesthetically appealing bricks. These bricks can be sold as a semi-face brick for a significantly better margin (see below for differentiation between plaster and face bricks). This improved margin on a portion of the bricks produced can be quite lucrative for a clamp kiln manufacturer, and therefore clamp producers would prefer not to risk losing it.

To date, notwithstanding the advantages offered, the alternative firing technology that has garnered the most press in South Africa cannot recreate a reducing atmosphere (in its current guise). With a reasonable capital investment into the construction of a Vertical Shaft Brick Kiln (VSBK) plant (as opposed to almost no capital investment in the construction of a clamp kiln), a brick producer can drop firing energy usage to some 30% – 50% of that used in a clamp kiln and greatly reduce its carbon footprint (De Giovanetti & Volstedt, 2013). With energy costs making up to 40% of the cost of producing a brick, the potential for significant cost savings is clear. Additionally, clamp kilns

typically produce as much as 15% – 25% waste, due to their uncontrolled nature, whereas the pilot VSBK plant in South Africa is running at 2% waste (De Giovanetti & Volsteadt, 2013). The industry game-changing potential of this technology (over clamp kilns) is clear, but it is not the only option. Hoffman kilns or derivatives thereof enjoy continued popularity in some parts of the world. In South Africa, a common term for a Hoffman derivative is the transverse arch kiln, of which there are a few examples in operation. Zig-Zag kilns also operate effectively in many parts of the world and there is currently much interest in bringing this technology to South Africa. As per VSBKs, Hoffman and Zig-Zag technologies promise efficiency gains and pollution and waste reduction over clamp kilns, and may also be able to recreate a similar reducing atmosphere to clamp kilns. Nevertheless, most of these simple technologies - despite their advantages over clamp kilns - suffer from similar maladies, as listed below.

- VSBK, Hoffman and Zig-Zag technologies are specifically firing technologies. Hoffman and Zig-Zag can handle some limited drying, whereas VSBK has no capacity for drying. Therefore, many producers relying on these technologies will still be influenced by the weather or will require other energy sources to supply heat to separately constructed dryers.
- These simple technologies often make use of manual handling of each brick in the unfired state. This significantly reduces the potential to produce a top quality product and potentially adds to the amount of waste produced.
- Simple technologies are generally labour intensive and less suited to automation, and therefore more prone to process issues. Additionally, similar reasons can limit the scalability of the technology. Particularly with VSBKs, the ability of these technologies to replace high output clamp yards remains unproven.
- With VSBKs, the firing atmosphere is currently exclusively an oxidising environment. This has implications with regards to the

potential for increased margins on the production of facing bricks. Also, due to the weight-bearing nature of the set product, VSBKs have limitations with regards to the percentage of voids in the bricks produced.

2.1.3 Brick Types

When a house is constructed using face brick as the outer wall, the current norm in most areas of South Africa is that the outer walls should be of cavity wall construction (Grobelaar, 2006). This method of construction prevails due to its damp sealing characteristics and energy efficiency. Generally, the outer face brick wall (outer 'skin') encloses a cavity which is in turn enclosed from the other side by another brick wall. The inner 'skin' is built from plaster brick which is usually plastered to create the smooth, visible surface which most people paint. As plaster bricks are no longer visible after plastering, they are generally not of as high or uniform quality as the face brick on the outside.

As a general rule, that which can be seen – the face brick – attracts far more attention in the design and specification stage than that which cannot be seen – the plaster brick. The architect, developer or eventual occupant of the building is generally interested in the aesthetic appeal of the structure and hence pays particular attention to the choice of face brick. The plaster brick on the other hand, is generally chosen on the basis of price, quality and ease of use. This choice is often made by the builder or contractor – a different scenario to that of the face brick.

Naturally, both face brick and plaster brick are affected by a few similar issues. These include the service of the sales organisation, availability of the product and the price. However, the commodity nature of a plaster brick is inescapable and they are far more price-sensitive than face bricks. This adds to the challenges faced by plaster brick manufacturers in South Africa. With reference to SANS 227:2007, the common nomenclature and tolerances for clay brick units

Table 1: Common nomenclature and tolerances for clay masonry units (SANS 227:2007)

TYPE	S A N S Code	DESCRIPTION	Tolerances (mm) over average 32 units (individual units as applicable)		
			Length	Width	Height
FACE BRICK	FBX	Face Brick Extra Clay bricks that are selected or produced for their durability and high degree of uniformity of size, shape and colour.	± 2.5 (± 5)	± 1.5 (± 3)	± 1.5 (± 3)
	FBS	Face Brick Standard Clay bricks that are selected or produced for their durability and uniformity of size and shape.	± 3.5 (± 7)	± 2 (± 4)	± 2 (± 4)
	FBA	Face Brick Aesthetic Clay bricks that are selected or produced for their durability and aesthetic effect deriving from non-uniformity of size, shape or colour.	-	-	-
NON-FACE (PLASTER) BRICK	NFP	Non Facing Plastered Clay bricks suitable for general building work that is to be plastered.	± 3.5	± 2	± 2
	NFX	Non Facing Extra Clay bricks suitable for use, plastered or un-plastered, for general building work below damp-proof course or under damp conditions or below ground level where durability rather than aesthetics is the criterion for selection.	± 3.5	± 2	± 2

made in South Africa and relevant to this plan are summarised in Table 2.1. The most common size of plaster and face brick made in South Africa is the "Imperial Brick" with dimensions of 222mm long x 106mm wide x 73mm high. Imperial-sized brick products may be solid or may have holes through it (coring) for weight reduction, but either way, can be regarded as a commodity product - "a product that is the same as other products of the same type from other producers or manufacturers" (Cambridge University Press, 2014)).

2.2 Brick Sector Production Levels and the Construction Industry

It is estimated that there are about 100 industrial brick producers in South Africa, representing a total production capacity of approximately 3.5 billion bricks per year (CBA, 2014).

Construction contributes significantly to South Africa's economy, but has been in decline over the past seven years. The growth witnessed in the run up to the 2010 World Cup – between 2004 and 2007 – has not been seen since. 2008 saw the start of the decline with investment dropping by almost 12% in 2010. Growth has been relatively flat since then. The decline has led to intense margin pressure and manufacturers operate at extremely slim profit margin, often between just 2% and 3%.

The total income for the construction industry in 2014 was R395 026 million. The largest contributor related to Civil Engineering Structures (37%), followed by Buildings (23%).

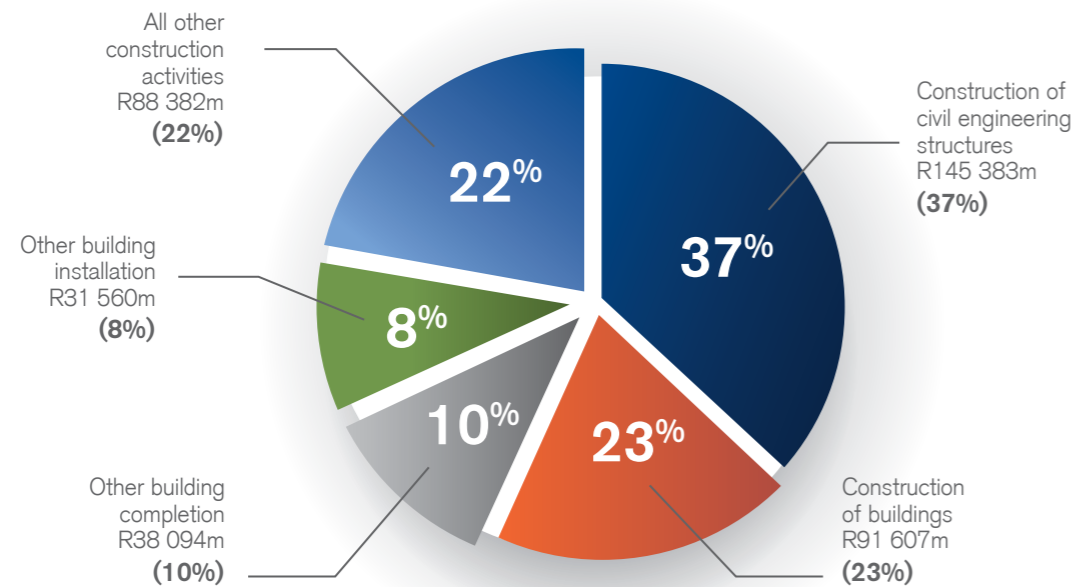


Figure 3: Income from the construction industry

Discussions with brick makers have indicated that most have substantially reduced production and are now operating at well below capacity, given the weak demand.

2.3 Breakdown of Kiln Technologies and Number of Sites

A breakdown of the split of South African brickworks in terms of kiln technologies employed is shown in the following charts.

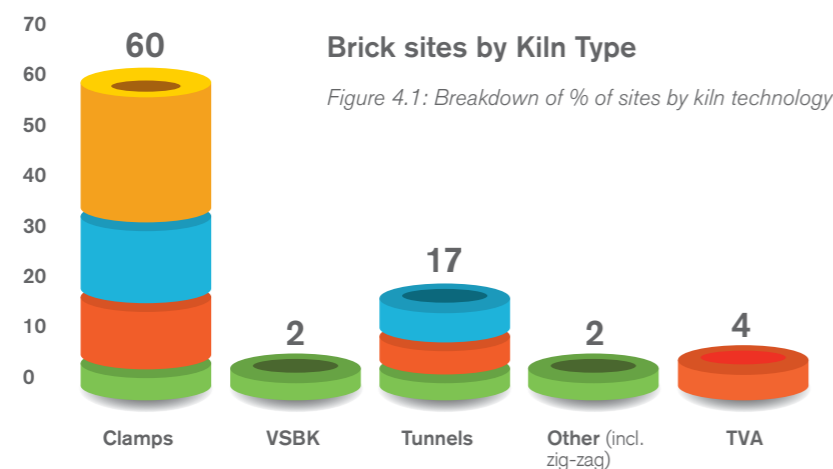
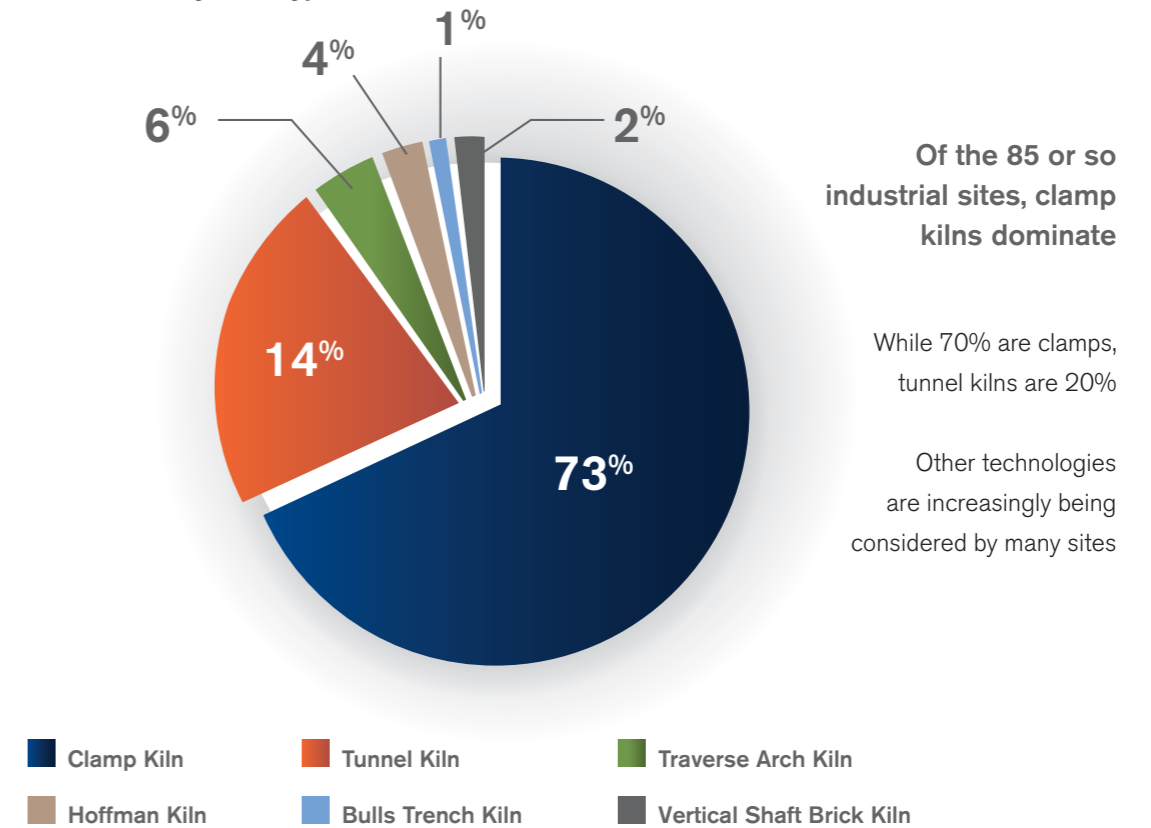


Figure 4.1: Breakdown of % of sites by kiln technology

Brick sites by Kiln Type



Of the 85 or so industrial sites, clamp kilns dominate

While 70% are clamps, tunnel kilns are 20%

Other technologies are increasingly being considered by many sites

Figure 4.2: Breakdown of % of sites by kiln technology

The vast majority (more than two-thirds) of South African brickworks employ clamp kiln firing technology, followed by tunnel kilns (14% of brickworks). Traverse 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%).

The energy intensity of the firing process varies considerably depending on the kiln type. A detailed comparison of specific energy consumption (SEC) in South Africa and abroad by kiln types is given in Chapter 3.



3. Benchmarks

3.1 Introduction

It is estimated that there are 300,000 brick kilns throughout the world manufacturing 1,500 billion bricks per year. Coal is by a large margin the main fuel used for brick-making; it is estimated that the brick industry consumes 50 million tonnes of coal per year out of 7,000 million tonnes mined each year. In term of emissions, the brick industry is responsible for about 100 million tonnes of CO² per year out of 8,000 million tonnes released each year from fossil fuels. Along with other industries, brick makers will benefit from reducing their CO² emissions by reducing their fuel costs per brick and their liability for any carbon taxes now or in the future. This chapter looks at the performance of various types of kilns from around the world, highlighting the differences in efficiency and the potential for energy reduction. Benchmarks can be applied at multiple levels, including:

1. Site specific benchmark;
2. National sector benchmarks;
3. International sector benchmarks.

1. Site Specific Benchmark

The site specific benchmark is used to drive

continuous improvement in a business through a quality management process and to measure the benefits derived from the process decisions.

In the example below, the energy consumption of a UK brick factory is plotted versus time. On the left-hand side of the graph, the red mean shows the average energy consumption before any measures were taken. It shows the high variability of energy consumption throughout the year prior to the adoption of any performance targets. The company instigated a performance monitoring programme using a benchmark – the green line- and rapidly saw its energy consumption naturally stabilising below their previous mean, thus saving energy by simply carefully monitoring their energy consumption and responding immediately to any deviation above the benchmark.

All the savings were achieved simply by improving current practices and no investment was required. The right-hand side of the graph shows the additional savings that the company calculated it could achieved through investment in new energy saving opportunities. The stable operating performance enabled the business case to be more accurately calculated and a more compelling case made to the board of directors.

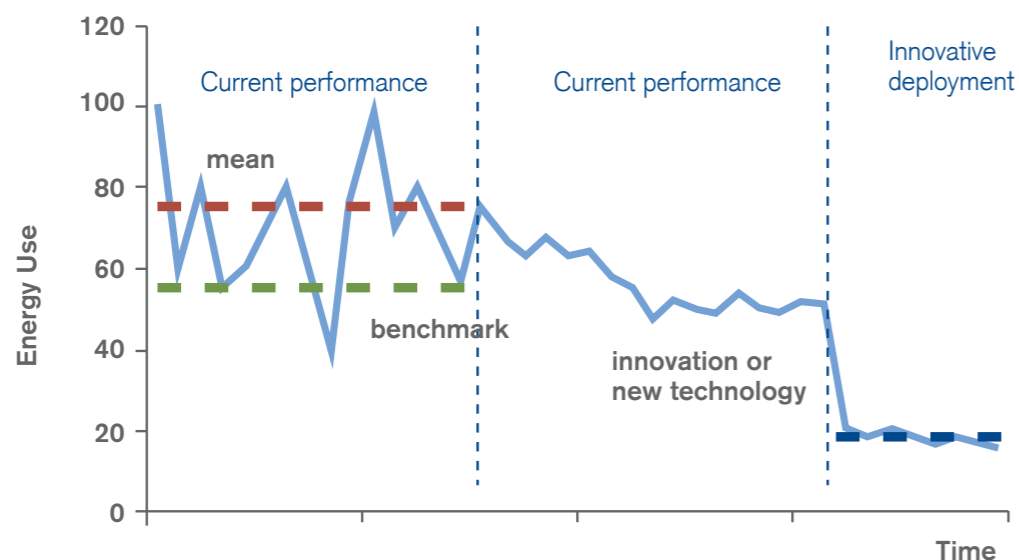


Figure 5: Example of reduction of energy consumption through personal benchmarking

2. The Sector Benchmark

better or worse than other sites.

Sector benchmarks are used to measure how a company is performing against its competitors and to identify the reasons for the difference. It helps the company to understand its relative competitive position.

Sector benchmarking requires cooperation between manufacturers. There is a common interest for brick manufacturers to maintain a competitive position versus brick substitutes (e.g. cement, glass, stone, wood, etc.).

Figure 7 depicts a real example of sector benchmarking undertaken for the UK brick market. Each factory's electrical and thermal energy consumption has been plotted in the graph and linear regressions show the market averages. A site which is below the regression line is more energy-efficient than the market average, while a site which is above the line is less energy-efficient. This type of exercise is valuable for every company to compare itself against the rest of the market.

The R² values on the regression lines show the degree of correlation between the regression and the data. A value less than 0.5 means there is little correlation and above 0.8 there is a strong correlation.

Figure 6 illustrates a hypothetical market with a gaussian shape. It shows the importance of sector benchmarks in order for factories to know their position in the market and identify why they are

Figure 6: Fictive example of sector benchmarking

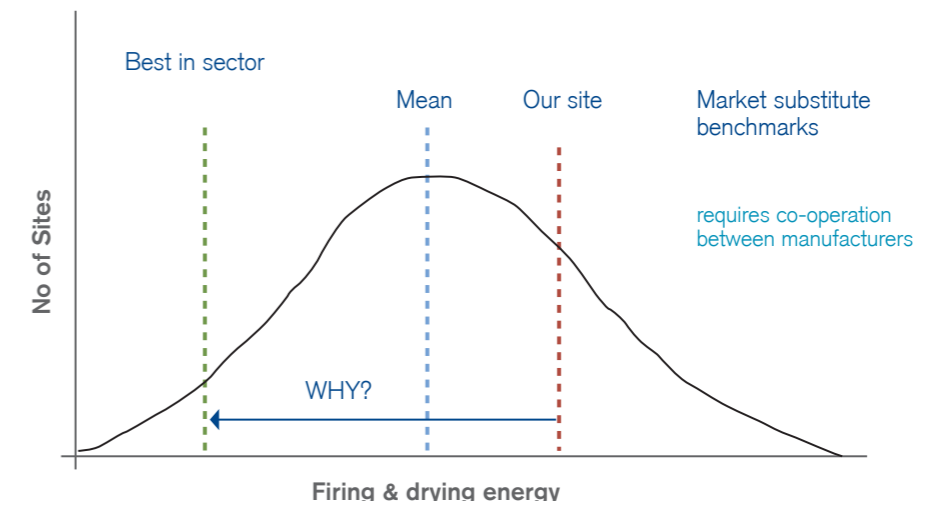
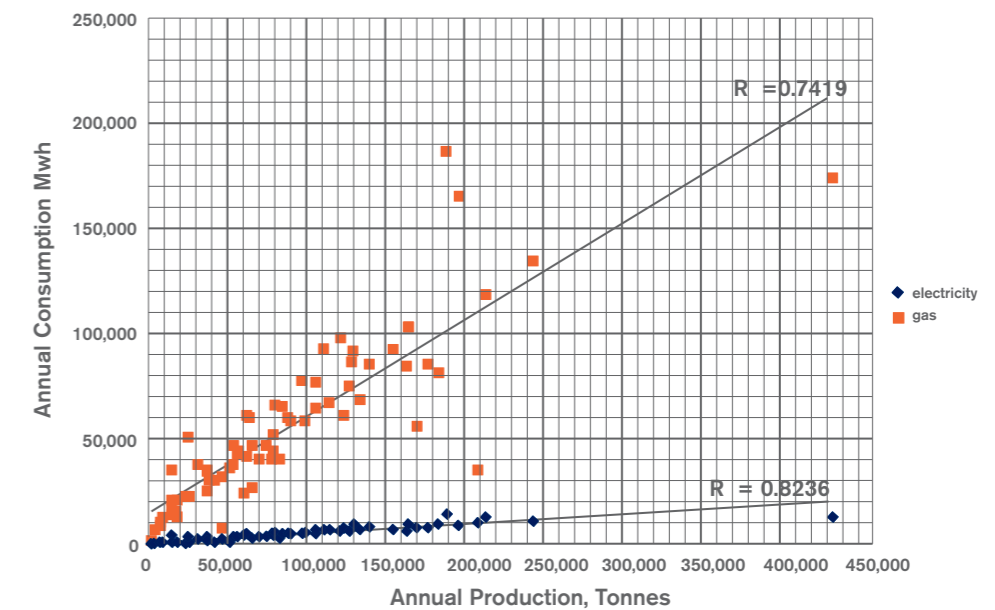


Figure 7: UK brick sector benchmarking



3. The International Sector Benchmark

Finally, the national sector's performance can be compared to international markets, to evaluate how they are performing as a whole against other countries. This is a similar approach as the national sector benchmark, but comparing markets rather than individual sites. This section examines the energy consumption of kilns used throughout the world. It draws on published data and also on detailed information from the UK sector held by the Carbon Trust.

Clay bricks require heat to dry them and to fire them. Drying requires low temperature heat (below 150°C) to evaporate the water in the clay, whereas firing requires high temperatures of 1000°C or above. This heat is usually provided by a fossil fuel such as coal, oil or natural gas, however the presence of organic matter in clay can also contribute significantly to the heat requirement for firing. For example the lower Oxford clays in the UK used to make fletton bricks contain around 2% - 4% combustible carbon, which is almost sufficient to fire the bricks without the addition of more fuel.

Most data included in this section excludes the natural organic carbon in the clay and accounts only for purchased fuels.

Energy consumption in this report is reported as a specific energy consumption (SEC) representing the amount of energy required to fire a unit mass of brick. Where possible we have used MJ/kg.

▪ The United Kingdom

Within the UK, the majority of bricks are produced using modern tunnel kilns using natural gas for the fuel. The UK - like the rest of the EU and North America - tends to have large mechanised factories using much less labour than many brick factories in other countries, such as India, China and South Africa. A reliable electricity supply is essential for these factories as brick making, drying and firing processes all rely on power to operate machinery and air movement equipment. Electricity consumption is around 8% of the total energy consumption for brick making in the UK.

A survey of 73 brick kilns in the UK sector found a wide range of thermal efficiencies for the firing and drying processes as shown in the table below.

Country	Technology	¹ SEC MJ/kg	² SEC MJ/kg
UK	Intermittent kiln; Firing only	3.7	
UK	Best Practice Fuel UK Drying & Firing; Tunnel kiln; Moisture content 15%	1.3	
UK	Best Practice Soft Mud Drying & Firing; Tunnel kiln; Moisture content 28%	1.8	
UK	Drying & Firing; Mean of 73 kilns	2.3	
EU	Drying & Firing; Tunnel kilns		2.3

Sources: ¹Carbon Trust, 2012; ²IEA, 2007

Table 2: Benchmarking of specific energy consumption (SEC) for kilns in the UK

▪ China

China is the largest brick producer in the world, manufacturing 750 billion bricks per year, with the majority of these being produced in continuous chamber kilns (Clean Air Task Force, 2010). China does deploy other technology as well, including clamp, intermittent, tunnel and Vertical Shaft Brick Kilns (VSBK).

Country	Technology	¹ SEC MJ/kg	² SEC MJ/kg
China	Intermittent kiln	2.47	2.5
China	Annular kiln with natural drying	1.16-1.46	1.2-1.5
China	Annular kiln with artificial drying	1.39-1.56	
China	Tunnel kiln	1.29-1.52	1.3-1.5
China	VSBK	none found	

All energy consumption includes the energy requirement for drying unless stated otherwise.
Sources: ¹Swiss Agency for Development and Cooperation; ²UNIDO, 2010

Table 3: Benchmarking of specific energy consumption (SEC) for kilns in China

▪ India

India is the second largest brick producer in the world, manufacturing 140 billion bricks per year, with 70% of production from Bulls Trench Kilns (Clean Air Task Force, 2010). India also deploys other technology as well, including clamp, intermittent, tunnel and Vertical Shaft brick Kilns (VSBK).

Country	Technology	¹ SEC MJ/kg	² SEC MJ/kg
India	Clamp	1.5-7	
India	Intermittent chamber kiln	3-11	2.9
India	Bulls trench Kiln	1.8-4.2	1.22
India	Hoffman Kiln	1.5-4.3	
India	Tunnel kiln	1.5-2.0	1.49*
India	Zig-zag kiln		1.12
India	VSBK		0.95

All energy consumption includes the energy requirement for drying unless stated otherwise.
*Includes heat required for drying
Sources: ¹Swiss Agency for Development and Cooperation; ²Sakkti Sustainable Energy Foundation, 2012

Table 4: Benchmarking of specific energy consumption (SEC) for kilns in India

▪ **Bangladesh**

Brick production in Bangladesh is around 50 billion bricks per year (Clean Air Task Force, 2010). Like India, the majority of kilns are Bulls Trench Kilns but with other kiln types that are regarded as less polluting becoming more popular, such as the Zig-zag kilns and VSBK.

Country	Technology	¹ SEC MJ/kg	² SEC MJ/kg
Bangladesh	Intermittent Kiln		2-4.5
Bangladesh	Bulls Trench Kiln	1.3-1.9	1.2
Bangladesh	Hoffman Kiln	0.9	
Bangladesh	VSBK	1.2	

All energy consumption include the energy requirement for drying unless stated otherwise.
Sources: ¹ESMAP, 2011; ²UNIDO, 2010

Table 5: Benchmarking of specific energy consumption (SEC) for kilns in Bangladesh

Technology	Country	SEC MJ/kg
Clamp	India	1.5-7
Intermittent Chamber Kiln	UK	3.7
	China	2.5
	India	3-11
	Bangladesh	2-4.5
Bulls Trench Kiln	India	1.8-4.2
	Bangladesh	1.2-1.9
Hoffman Kiln (including annular kiln)	China	1.2-1.5 (1.4-1.6)
	India	1.5-4.3
	Bangladesh	0.9
VSBK	India	0.95
	Bangladesh	1.2
Tunnel Kiln	UK best practice (15% moisture)	(1.3) 0.7
	UK best practice (28% moisture)	(1.8) 0.8
	UK mean	(2.3) 1.2
	EU mean	(2.3)
	China	1.3-1.5
	India	1.5-2.0
Zig Zig Kiln	India	1.1

Data in brackets include heat for drying. All other data excludes heat for drying.

Table 6: Summary of specific energy consumption (SEC) benchmarking by technology

Table 6 shows that the best Hoffman and VSBK kilns can be as efficient as modern tunnel kilns. This suggests that with the right technology and management practices, these technologies can be operated at global best practice levels of energy efficiency. Clamp and intermittent kilns are clearly a lot less efficient. Using this table and the heat balances, we can construct some firing energy benchmarks for manufacturers to compare themselves against, based on the technology they are deploying, and thus determine the level of potential savings

they could realise by deploying some of the best practices recommended within this report.

From energy surveys carried out for a sample of brickworks in the country, the range of SEC for South African kilns was compared to international figures. It is evident that the energy intensity of clamp kilns varies considerably in South Africa but is comparable to international figures. The tunnel kilns assessed have higher than international energy intensities, whilst TVA kilns are in the international range of SEC.

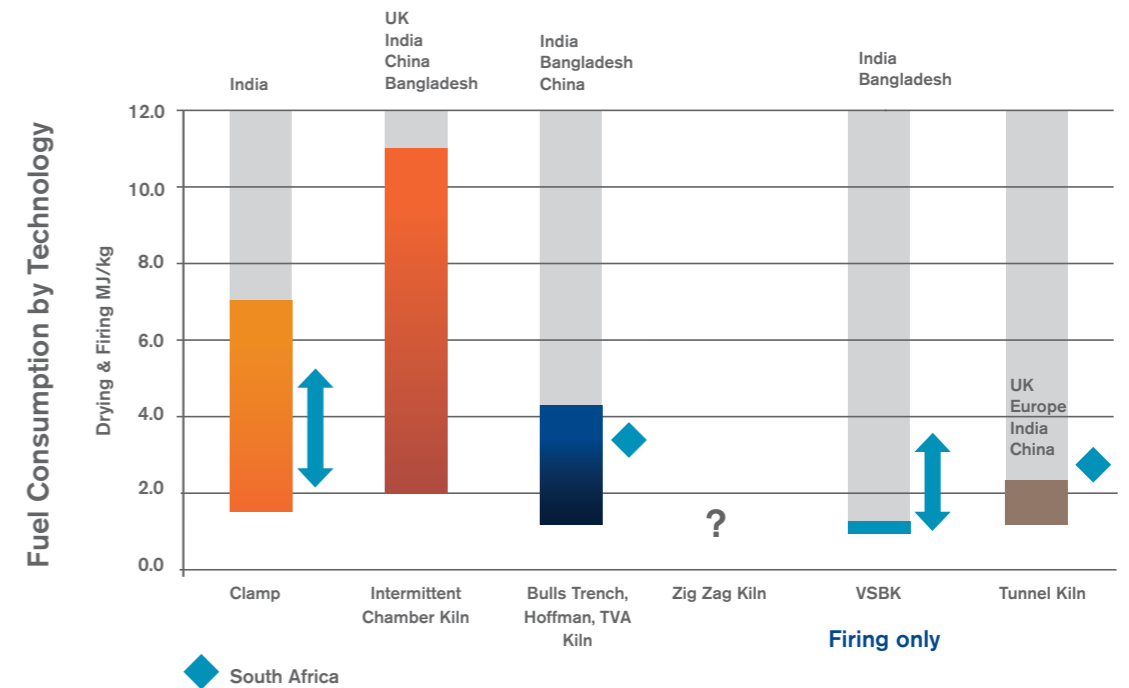


Figure 8: Summary of international (purple) and South African (green) ranges of specific energy consumption (SEC) for the drying and firing processes by technology

Non-continuous kilns: SEC data from South African Clamp kilns (in green) are well within the range of international clamp kilns, with the most energy efficient ones approaching the international benchmark. However, the range is very large, showing margin for significant energy efficiency improvements. No intermittent chamber kilns were reported in South Africa.

There are currently two VSBKs in South Africa, one of them as efficient as the best VSKBs abroad and the other well above. It is important to note that VSBKs' SEC represented in the graph are for firing only; hence, it cannot be compared with other technologies whose SEC includes the drying process. Other South African continuous kilns (tunnel and TVA kilns) seem to be in the lower end or above their international counterparts, thus indicating significant opportunities for energy savings.

Continuous kilns: No data is provided for Zig-zag kilns as data for only one kiln was found in literature, which is insufficient to draw relevant conclusions.

3.1.1. Continuous Kiln Benchmarks

Continuous Kilns	Best Practice	Theoretical Minimum
	MJ/kg	MJ/kg
Firing only	0.7	0.6

Table 7: Best practice and theoretical minimum SEC for continuous kilns

The theoretical minimum was computed, considering the following assumptions:

- 2% moisture content of bricks entering kiln
- Bricks leaving the kiln cooling zone at 200°C
- 100% excess air
- Exhaust is 200°C
- Structural loss of 0.2 MJ/kg fired brick

Note: other values for a theoretical minimum could be obtained using different assumptions. The table shows that the best practice kiln is close to the theoretical minimum calculated. These two values should be used by continuous kiln operators as targets for energy efficiency improvements.

3.1.2. Advantages and Disadvantages of the Main Brick Kiln Types

In this section, the various kiln types were assessed as Low, Medium and High, based on nine criteria. Negative aspects of the kilns are flagged in red, while positive aspects are marked in bold. Note that it is a non-exhaustive list and other criteria may come in the balance when comparing or choosing a new kiln to fire the bricks without the addition of more fuel.

	Clamp	Inter-mittent Chamber	Bulls Trench	Hoffman	Zig Zag	VSBK	Tunnel
Capital cost	Low	High	Low	Med	Med	Med	High
Labour cost	High	Med	High	High	High	Med	Low
Fuel cost	High	High	Med	Low	Low	Low	Low
Pollution	High	Low	High	Med	Med	Med	Low
Operator safety	Low	High	Low	Med	Med	Med	High
Level of control	Low	High	Low	Med	Med	Med	High
Quality variation	High	Low	High	High	High	Med	Low
Flexibility	Low	High	Low	Low	Low	Low	High
Electricity required	No	Yes	No	No	No	No	Yes

Table 8: Comparison between kiln types

It is clear from the table below that each type of kiln has its own advantages and disadvantages. Tunnel kilns come out as the option with the highest number of advantages, especially around control opportunities and quality, but it is also the most expensive one. VSBKs have very few weaknesses, offering good overall performance with reasonable capital cost, with its main disadvantage being low flexibility. Hoffman and Zig-zag kilns are interesting options, although less attractive than VSBKs and Tunnel kilns based on the table above. Intermittent chamber kilns have many advantages but are expensive both in term of capital cost and fuel consumption. Finally, both Clamp and Bulls Trench Kilns have a fairly high number of disadvantages, but remain the cheapest options.

4. Performance of the Sector

4.1. Where is Energy Used in Brick-making?

A number of energy audits have been carried out in South Africa showing a breakdown of the total energy use in brick factories. Note that the analysis below is only based on a small sample of the South African brick plants and does not represent the market's averages.

steps in a brickworks by a large margin. These are also the only processes using thermal energy rather than electrical energy. Thermal energy use is analysed in the next section using a tool developed for this purpose. This section focuses on the use of electrical energy only.

The following two tables provide examples of the breakdown of electrical energy use for three sites using continuous kilns and three site using clamp kilns in South Africa.

Drying and firing are the most energy-intensive

	Sites operating continuous kilns	Site 1 (Tunnel kiln)	Site 2 (VSBK)	Site 3 (Tunnel kiln)
Motors	Crushers & Grinders	38%	28%	7%
	Extruder	32%	13%	11%
	Mixers	9%	9%	7%
	Conveyors	Incl. above	4%	4%
	Dryer & Kiln (mainly fans)	11%	39%	58%
	Pumps & Compressors	2%	5%	2%
	Others (e.g. lightings, office, etc.)	8%	2%	11%

Table9: Breakdown of electrical energy use in three South African brick factories using continuous kilns

Breakdown of electrical energy use in three sites operating continuous kilns

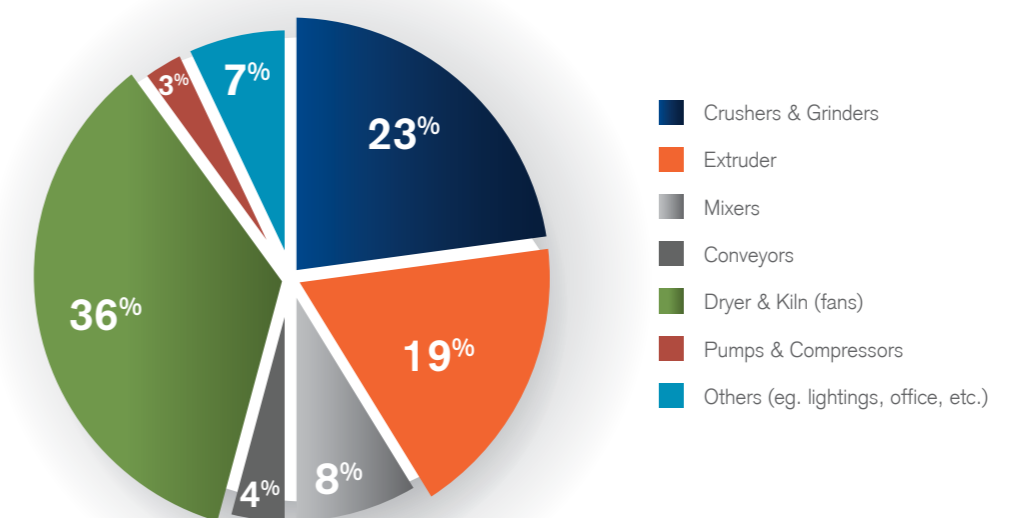


Figure9: Average breakdown of electrical energy use for three South African brick factories using continuous kilns

	Sites operating clamp kilns	Site 1 (Clamp & fixed kiln)	Site 2 (Clamp)	Site 3 (Clamp)
Motors	Crushers & Grinders	16%	7%	50%
	Extruder	23%	38%	40%
	Mixers	19%	39%	
	Conveyors	15%	7%	Incl. above
	Fans	10%	0%	0%
	Pumps & Compressors	10%	4%	Incl. above
	Others (e.g. lightings, office, etc.)	7%	5%	10%

Table 10: Breakdown of electrical energy use in three South African brick factories using clamp kilns

Breakdown of electrical energy use in three sites operating clamp kilns (one site also operating a fixed kiln)

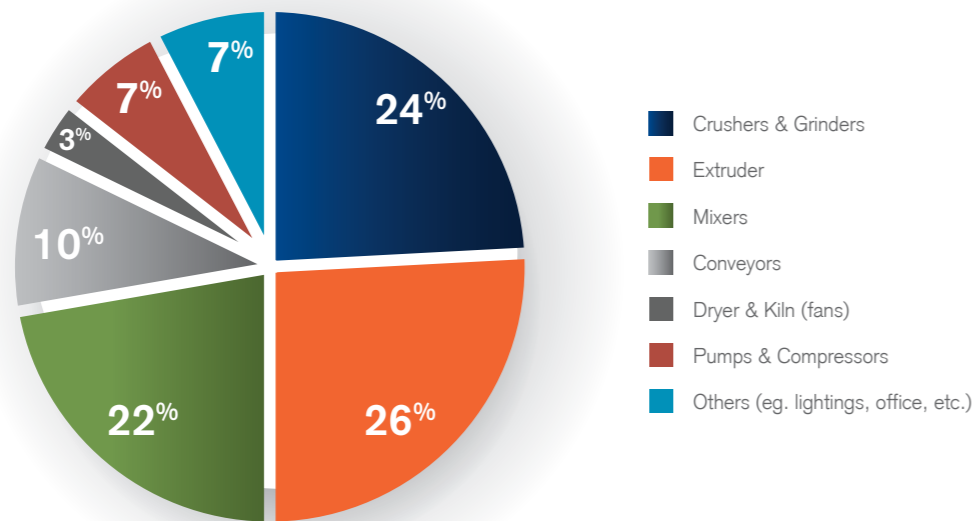


Figure 10: Average breakdown of electrical energy use for three South African brick factories using clamp kilns

In clamp kiln sites, motors, in particular extruders, crushers and mixers, dominate the electricity consumption. All motors represent over 80% of the electrical energy use in clamp kiln sites. There is therefore a significant incentive to improve motors' efficiency through, for example, motor efficiency retrofits on less efficient motors, replacing oversized motors or replacing existing standard solid V-drive belts with other types of belts. However, electricity is also used in ancillary processes such as compressors, lighting, small power and offices. Compressor control, leak surveys and energy efficient lighting are all well-known and worthwhile initiatives to reduce ancillary consumption.

In sites operating continuous kilns, the picture is different; fans used for the drying and firing processes make a major part of the total electricity consumption. As a result, fan system optimisation (e.g. type of fans, de-commission of some fans, use of variable speed drive, etc.) is a very attractive energy saving opportunity for continuous kilns. The electrical energy saving from fans is closely related to the efficiency of heating, hence the optimisation of thermal energy use can also result in electricity savings.

Similar to clamp kiln sites, extruders, crushers and mixers are responsible for most the rest of the electricity consumption.

4.2. Electricity Bills

A significant reduction in energy bills can be achieved through better energy management. Audits have revealed that in several instances, network demand charges are responsible for almost half of electrical energy costs.

Electricity bill	Site 1	Site 2
KWh energy charge	57%	53%
Network demand charge	38%	47%
Service charge	5%	0.4%

Table 11: Breakdown of electricity bills for two South African brick factories

A notified maximum demand is set for each plant and if this demand is exceeded, penalties are incurred. Such penalties resulting from uncontrolled maximum demand can account for a high percentage of the total monthly electricity bill.

The Notified Access Charge (NAC) is a fixed kVA value which should never be exceeded. An uncontrolled or unplanned kVA event will result in a penalty for the next 12 months ahead.

The maximum or peak demand in kVA is billed according to the half hour of the month in which the maximum demand was reached. Thus the half hour in the month in which the average consumption was the highest, is the peak demand

for that specific month. The peak demand most probably occurs when large energy consumers are starting up simultaneously. Therefore, there is an opportunity for savings on the electricity bill, should maximum demand control be implemented. Real time measurement and monitoring with a built in automated maximum demand control feature give the ability to prevent any unplanned energy spikes.

Significant savings can also be achieved by moving outside of peak periods and minimising energy consumption during high season. The following table shows three examples of brick factories with an average of 20% energy use during peak periods, resulting in a large increase in total electricity costs.

KWh energy charge	Site 1	Site 2	Site 3
Standard periods	58%	60%	44%
Off-peak periods	26%	17%	39%
Peak periods	16%	23%	17%

Table 12: Breakdown of KWh energy charge for three South African brick factories

5. Thermal Energy Model

5.1. Introduction

Thermal energy is an area that is often neglected when considering reducing energy consumption. Energy audits are typically focussed on electrical energy, as thermal energy losses are often harder to identify and quantify. Nevertheless, heat used in the drying and firing processes accounts for a majority (typically over 90%) of the total energy consumption in a brick factory.

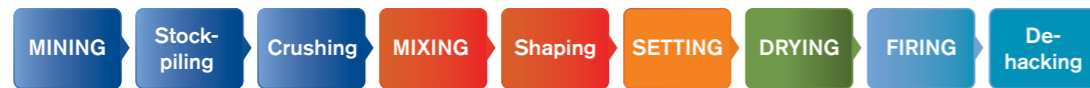


Figure 11: Brick manufacturing process

In response to this opportunity, the project developed a thermal energy tool to enable brick plant managers to:

1. Establish a full breakdown of thermal energy flows in their manufacturing process;
2. Identify main areas of thermal energy losses;
3. Identify relevant opportunities to reduce energy consumption;
4. Quantify these opportunities and benchmark their plant with best practice brick plants internationally.

The free tool is available to anyone and can be found on CBA's website:

<http://www.claybrick.org.za/energy-efficiency-guidelines/thermal-model>.

The tool was developed for all types of continuous or fixed kilns, e.g. tunnel kilns, VSBKs, Hoffman kilns, Zig-zag kilns and BTKs. It cannot be used for clamp kilns, which are batch processes. Whilst a model with good accuracy can be built for continuous kilns, a clamp kiln model would involve a higher degree of assumption and would bring less value to clamp kiln managers.

The overarching principle of the tool relies on the accurate estimation of each thermal energy flow in the manufacturing process, i.e. in the drying (if relevant) and firing processes.

Figure 12 represents the energy streams quantified by the model.

Thermal energy flows diagram of the system

- > The purpose of the model is to generate an energy flow diagram (Sankey) as accurate as possible with the aim to recommend relevant energy saving opportunities to the brick factory manager

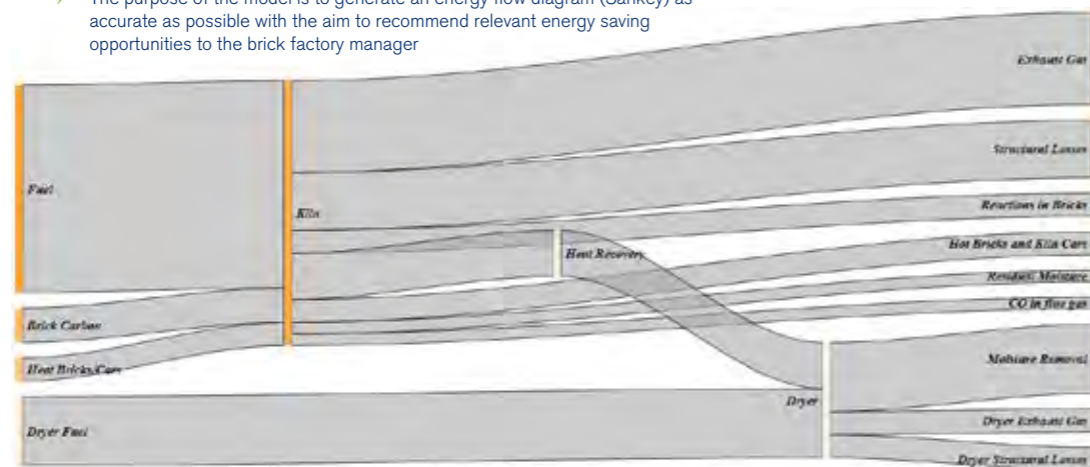


Figure 12: Energy flows of the analysed system

Once these streams have been quantified, a set of best practice opportunities are selected based on the model outputs. Hence, instead of a long list of energy saving opportunities, only

a subset of opportunities which best match the areas of thermal energy losses are presented to the user. Total potential savings are indicated in term of energy (MJ) and money (Rand).

5.2. Structure of the Model

The model was built using Microsoft Excel and can run on every computer, although some older versions of the software might prevent it from using embedded Macros. The file is structured in three main sheets:

1. The inputs interface;
2. The output sheet showing the energy balance of the system;
3. The best practice sheet generating relevant opportunities.

Structure of the model

1. Data of a specific plant are entered in the Input sheet
2. The model calculates the energy balance
3. A list of energy saving opportunities automatically generated

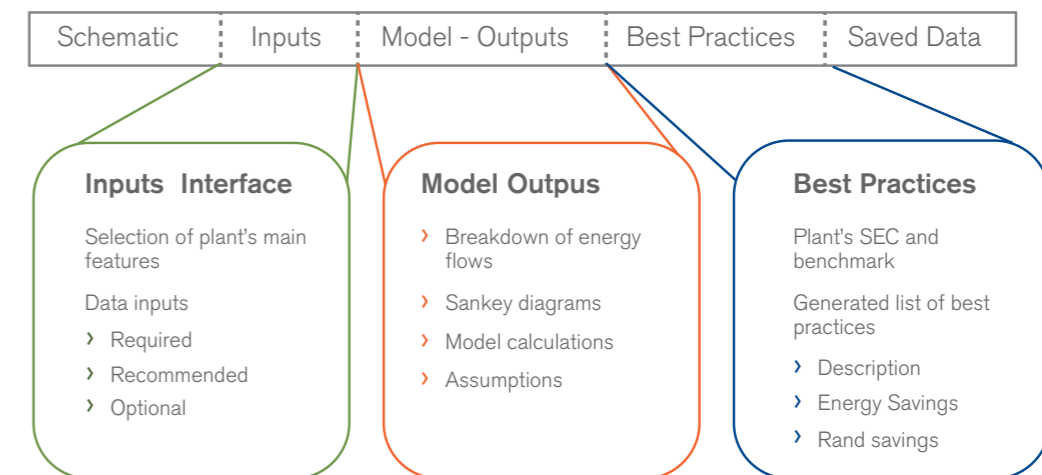


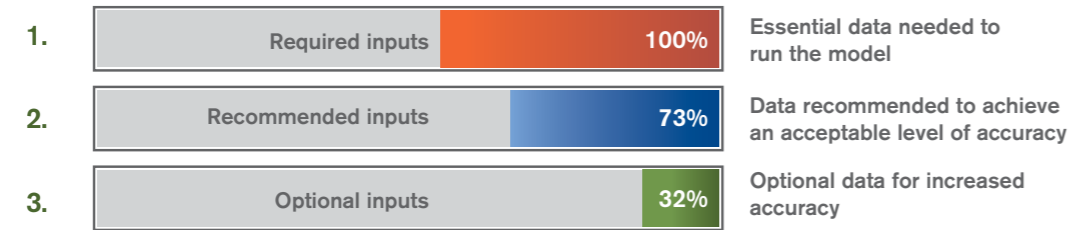
Figure 13: Structure of the Excel tool

A fourth sheet called "Saved Data" can be used to store data. This data can then be sent to the inputs sheet, thus saving time and avoiding the need to type each data in the inputs sheet every time one wants to visualise the outputs. For example, a plant manager might want to save plant data on year 1, year 2 and year 3 for comparison purposes.

▪ **The Inputs Sheet**

The more data input into the model, the more accurate the outputs are. Therefore, it is encouraged to provide as much data as possible. The various data has been broken down into three categories, each one being monitored by a progress bar.

To enable managers with limited data on their plant to use the model, inputs have been broken down into three categories. The completeness of each category indicated as below:



Any recommended or optional inputs which are not provided by the user will be assumed by the model. Categories of inputs include:

- Production
- Fuels
- Bricks
- Kiln & Dryer
- Exhaust gas
- Kiln Cars
- Heat recovery

Figure 14: The three categories of inputs

Required inputs include data on the production, the mass and moisture content of bricks and the fuel consumption. Recommended inputs include data on the kiln dimensions, the temperature of kiln walls, the temperature of bricks and kiln cars,

leaving the kiln and the temperature and flow rate of the exhausts. Any recommended or optional inputs not provided by the user is estimated by the model using the required inputs and literature values.

▪ **The Outputs Sheet**

The various energy flows for the firing process (and drying process if relevant) are automatically computed in a table based on the data given in the inputs sheet. These data are also represented

in a diagram called "Sankey", where each energy flow is represented by an arrow whose height is proportional to the amount of energy of the flow.

Energy Out	Model outputs	kJ/hour	kJ/kg fired brick	%
Energy to remove residual moisture		220,570	73	5.3%
Energy for reactions in brick (dehydration, burn-off, vitrification)		603,103	200	14.4%
Energy lost in flue gas (exhaust losses)		1,145,156	380	27.3%
Energy from hot air extraction for heat recovery		321,509	107	7.7%
Energy lost through kiln walls (structural losses)		1,071,105	355	25.5%
Energy lost in kiln cars		110,250	37	2.6%
Energy lost from hot fired bricks		499,369	166	11.9%
Energy lost due to CO in flue gas		90,278	30	2.2%
Energy unaccounted for		137,006	45	3.3%
Total		4,198,347	1,392	100%

Table 13: Table showing an example of an energy balance for the firing process

The model always indicates a certain percentage of "Energy unaccounted for". This represents the amount of energy left that is not included in any of the quantified energy flows. The energy unaccounted for is typically positive, indicating that some energy is lost through other ways, such as non-insulated surfaces or sources of air ingress.

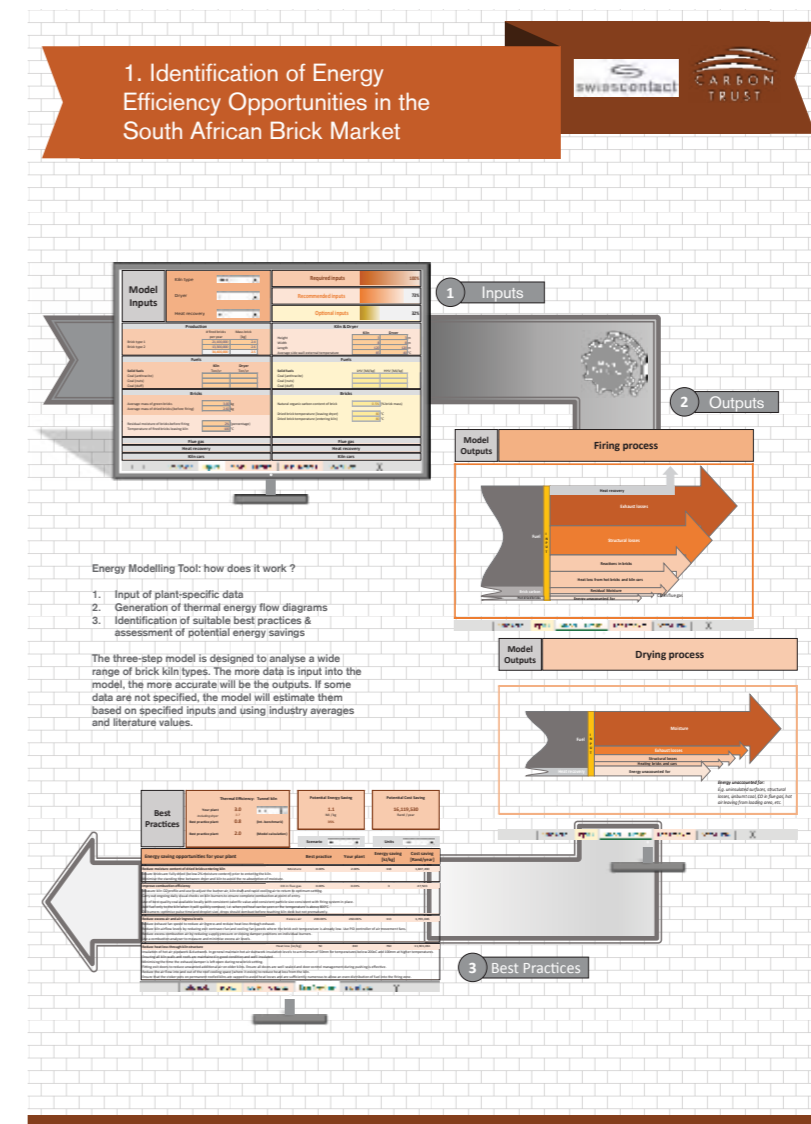
Each kiln has its own features and specificities that cannot be quantified by a general model. A high energy unaccounted for can also reflect inaccuracy in the measurements or in the model. There will always be some unaccountable energy and it is normal in even the best audits to be + or - 10%.

The detailed model calculations and assumptions made can be viewed on the same sheet.

▪ **The Best Practices Sheet**

Based on the model outputs, a list of best practices is automatically generated for the user. These selected best practices, grouped into categories, target areas responsible for the main thermal energy losses. For each category, a comparison is made with best practice plants and potential savings are calculated. The model considers two best practice scenarios; one being more stringent than the other, thus indicating higher potential savings.

As a result, plant managers can use the tool to identify set energy saving opportunities relevant for their kiln. The business cases for these opportunities can then be looked at in the long list of best practices in Chapter 5.



5.3. BestPractice Categories

The long list of best practices on the thermal energy side has been broken down into 10 categories. Each category is tested based on a specific criteria. If, for the tested criteria, the model indicates a higher value than the corresponding expected value for best practice plants, the category is highlighted and a list of related energy saving opportunities is indicated. For example, the specific criteria for Category 3 is the amount of CO (carbon monoxide) in the flue gas. If the model indicates a CO content above the best practice value of 500ppm, a list of opportunities on how to

improve combustion efficiency is indicated.

The table below summarises the 10 sections and their tested criteria. Typical observations and causes that can corroborate the model's analysis are also indicated.

Note that the table only shows the 10 sections, but no details on the best practices in each section is given. The full list of best practices can be found in Chapter 5.

#	Category	Observations	Cause	Tested criteria	Best practice
1	Reduce moisture content of dried bricks entering kiln	<ul style="list-style-type: none"> Shattered, broken or cracked bricks Excessive dampness or condensation in the stack 	<ul style="list-style-type: none"> Moisture content of bricks is too high 	Moisture level [%]	2%
2	Reduce moisture content of coal		<ul style="list-style-type: none"> Moisture content of fuel is too high 	Moisture level [%]	2%
3	Improve combustion efficiency	<ul style="list-style-type: none"> Black smoke emitted from chimney stack Carbon monoxide measured in chimney stack 	<ul style="list-style-type: none"> Combustion taking place at too low temperatures Insufficient combustion air reaching the fuel once it is above the combustion point, e.g. brick setting is too dense and air cannot reach the fuel for combustion Moisture content of bricks and/or fuel is too high 	CO in flue gas [ppm]	500

Table 14: Summary of the 10 best practice categories used in the model, as well as related observations, causes, tested criteria and best practice values

4	Improve efficiency of heating	<ul style="list-style-type: none"> Variable quality: <ul style="list-style-type: none"> Darker brick colours, hard, low moisture content, partially molten Lighter brick colours, weak brick, high moisture content Multi coloured darker bricks, possible black core and black surface. Some signs of melting Poor temperature control: <ul style="list-style-type: none"> Different parts of the same chamber or kiln car at different temperatures Peak temperature variable resulting in some bricks being over fired and some under fired 	<ul style="list-style-type: none"> Variable quality: <ul style="list-style-type: none"> Bricks over fired or underfired Bricks subject to reducing conditions Poor temperature control: <ul style="list-style-type: none"> Uneven fuel distribution Poor air circulation and exhaust pathways Kiln under too much suction Walls and roof in poor repair 	SEC [MJ/kg]	Depends on kiln type	
5	Reduce excess air and air ingress levels		<ul style="list-style-type: none"> Low exhaust stack temperatures & high exhaust flow rates 	<ul style="list-style-type: none"> Too much air being admitted into the kiln resulting in too much hot air leaving the kiln through the exhaust 	Excess air level [%]	200%
6	Reduce heat loss through kiln structure		<ul style="list-style-type: none"> Hot kiln walls and roof Uncontrolled air leaking into or out of the kiln through walls or roof 	<ul style="list-style-type: none"> Poorly maintained walls and roof Kiln under too much suction 	Heat loss through walls [kJ/kg]	200 kJ/kg
7	Reduce temperature of bricks leaving the kiln		<ul style="list-style-type: none"> Bricks are too hot at the kiln exit making them difficult to handle and wasting the heat energy that they contain 	<ul style="list-style-type: none"> The kiln or the firing cycle is too short is too short meaning there is insufficient time to cool the bricks properly and recover all the heat within the kiln Back flow of hot air from the firing zone into the cooling zone Brick setting is too dense to allow cooling air to reach and cool within the entire brick setting 	Brick temperature [°C]	100 °C
8	Reduce waste levels by improving the consistency of the raw materials		<ul style="list-style-type: none"> High number of wasted bricks 	<ul style="list-style-type: none"> Inconsistent particle size distribution Inconsistent moisture content 	Wastage [%]	2%
9	Heat recovery				Using heat recovery	Yes
10	Energy unaccounted for		<ul style="list-style-type: none"> All other energy losses that cannot be quantified in the above sections 	<ul style="list-style-type: none"> Uninsulated surfaces (ducts, lids, etc.), unburnt coal, hot air leaving from loading area, other sources of air egress, etc. 	Other losses [%]	5%

5.4. Case Studies

In this section, we will briefly analyse three case studies. The first case study is a tunnel kiln in the UK and the second and third case studies are South African tunnel kiln and VSBK respectively.

5.4.1. Tunnel Kiln in the UK

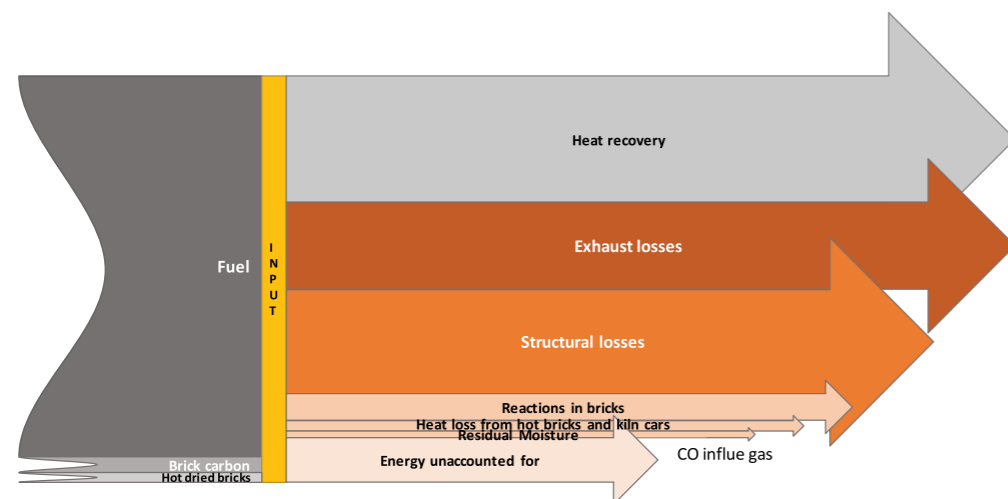
This is an old tunnel kiln located in England using

▪ Firing Process

Figure 16: Model results for the firing process of the UK tunnel kiln example displayed in tables and in a Sankey diagram

Energy In	kJ/hour	kJ/kg fired brick	%
Energy from fuels	28,579,134	2,856	93.7%
Energy from brick natural organic carbon content	1,235,004	123	4.1%
Energy from hot dried bricks and kiln cars	675,678	68	2.2%
Total	30,489,816	3,047	100%

Energy Out	kJ/hour	kJ/kg fired brick	%
Energy to remove residual moisture	510,018	51	1.7%
Energy for reactions in brick (dehydration, burn-off, vitrification)	2,001,120	200	6.6%
Energy lost in flue gas (exhaust losses)	6,537,307	653	21.4%
Energy from hot air extraction for heat recovery	9,482,992	948	31.1%
Energy lost through kiln walls (structural losses)	7,836,305	783	25.7%
Energy lost in kiln cars	39,222	%	0.1%
Energy lost from hot fired bricks	736,412	#%	2.4%
Energy lost due to CO in flue gas	29,347	"	0.1%
Energy unaccounted for	3,317,092	332	10.9%
Total	30,489,816	3,047	100%



natural gas as the only fuel. It has an external dryer using hot air recovered from the kiln. All required inputs were provided, as well as 73% of recommended inputs and 32% of optional inputs.

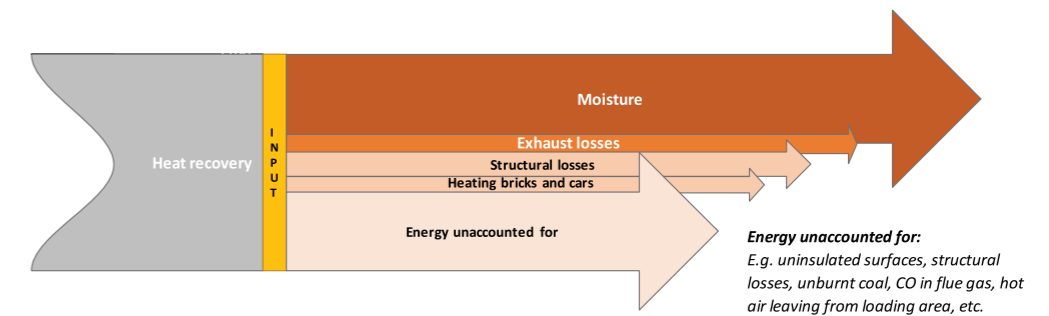
The outputs for the firing and drying processes are presented below (tables and Sankey diagrams).

▪ Drying Process

Figure 17: Model results for the drying process of the UK tunnel kiln example displayed in tables and in a Sankey diagram.

Energy In	kJ/hour	kJ/kg fired brick	%
Energy recovered from kiln	9,482,992	948	100.0%
Energy from fuels	-	-	0.0%
Total	9,482,992	948	100%

Energy Out	kJ/hour	kJ/kg fired brick	%
Energy to remove brick moisture	3,893,779	389	41.1%
Energy lost in flue gas (exhaust losses)	384,919	38	4.1%
Energy lost through dryer walls (structural losses)	1,061,454	106	11.2%
Energy lost in heating bricks	600,636	60	6.3%
Energy lost in heating kiln cars	75,042	8	0.8%
Energy unaccounted for	3,467,162	347	36.6%
Total	9,482,992	948	100%



From the energy balance above, some observations can already be made. Looking at the firing process, the energy lost through the kiln walls is very high and something should be done to reduce the structural losses. (Note that structural losses are the most difficult to estimate accurately due to large variations of the external wall temperatures). Exhaust losses are also high, however it is expected that exhaust gas accounts for about 20% of the total energy. We can also observe that very little energy is lost in kiln cars and fired bricks, indicating that they are leaving the kiln at reasonable temperatures. The very low energy lost due to CO in flue gas reflects a good combustion efficiency, which is typically expected with high excess air.

Finally, about 30% of the energy is hot air recovered and sent to the dryer. Looking at the dryer's Sankey diagram, we see that only 41.1% of the input energy is required to dry the bricks. Therefore, it is possible that too much hot air is sent to the dryer and energy could be saved by reducing the amount of fresh air blown in the kiln and then recovered.

Next, we look at the Best Practice Sheet. The SEC (Specific Energy Consumption) of the firing process is 2.9MJ/kg, compared to best practice tunnel kilns at 0.8MJ/kg based on international benchmarks, which shows that this kiln is a long way from being the most efficient one. The model calculates that, under a conservative scenario, 23% or 0.7MJ/kg of energy savings have been identified, which could bring the kiln's SEC to 2.2MJ/kg. This corresponds to a saving of nearly R11 million per year. Four areas are highlighted where tested criteria are above expected values for best practice kilns:

- Improving efficiency of heating (SEC of 2.9MJ/kg vs. 0.8MJ/kg)
- Reducing excess air and air ingress levels (excess air of 260% vs. 200%)
- Reducing heat loss through the kiln structure (heat loss of 783kJ/kg vs. 200kJ/kg)
- Energy unaccounted for (11% vs. 5%)

For each of these four categories a list of opportunities is given to suggest how these savings could be achieved (details are not provided here).

5.4.2. Tunnel Kiln in South Africa

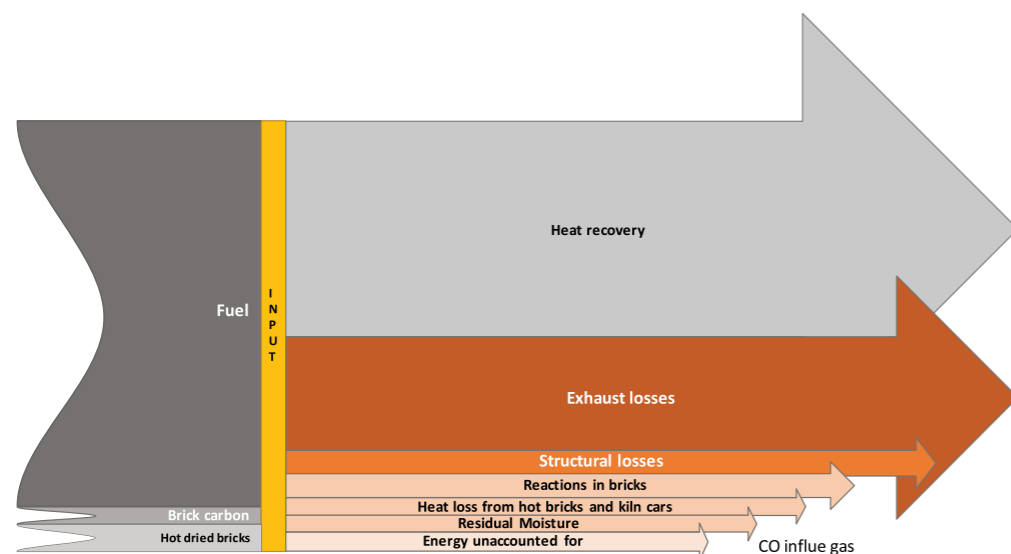
This is a tunnel kiln located in South Africa using heavy fuel oil and a waste product as fuels. It has an external dryer using hot air recovered from the kiln. All required inputs were provided, as well as 91% of recommended inputs and 63% of optional inputs. The outputs for the firing and drying processes are presented below (tables and Sankey diagrams).

Firing Process

Figure 18: Model results for the firing process of the South African tunnel kiln example displayed in tables and in a Sankey diagram

Energy In	kJ/hour	kJ/kg fired brick	%
Energy from fuels	18,970,757	2,483	92.6%
Energy from brick natural organic carbon content	181,678	24	0.9%
Energy from hot dried bricks and kiln cars	1,332,313	174	6.5%
Total	20,484,749	2,682	100%

Energy Out	kJ/hour	kJ/kg fired brick	%
Energy to remove residual moisture	527,579	69	2.6%
Energy for reactions in brick (dehydration, burn-off, vitrification)	1,527,772	200	7.5%
Energy lost in flue gas (exhaust losses)	7,809,580	1,022	38.1%
Energy from hot air extraction for heat recovery	13,814,249	1,808	67.4%
Energy lost through kiln walls (structural losses)	1,291,121	169	6.3%
Energy lost in kiln cars	303,188	41	1.5%
Energy lost from hot fired bricks	281,110	37	1.4%
Energy lost due to CO in flue gas	558,825	73	2.7%
Energy unaccounted for	- 5,628,674	- 737	-27.5%
Total	20,484,749	2,682	100%

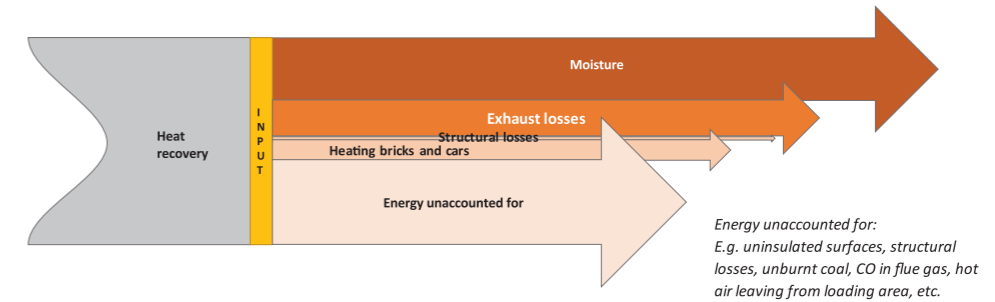


Drying Process

Figure 19: Model results for the drying process of the South African tunnel kiln example displayed in tables and in a Sankey diagram

Energy In	kJ/hour	kJ/kg fired brick	%
Energy recovered from kiln	13,814,249	1,808	100.0%
Energy from fuels	-	-	0.0%
Total	13,814,249	1,808	100%

Energy Out	kJ/hour	kJ/kg fired brick	%
Energy to remove brick moisture	4,170,001	546	30.2%
Energy lost in flue gas (exhaust losses)	2,397,103	314	17.4%
Energy lost through dryer walls (structural losses)	223,996	"	1.6%
Energy lost in heating bricks	736,316	96	5.3%
Energy lost in heating kiln cars	632,813	82	4.6%
Energy unaccounted for	5,654,020	740	40.9%
Total	13,814,249	1,808	100%



From the above energy balance, it can be observed that the structural losses are low and are not an area of concern. Most of the energy is found in the exhausts and in the heat recovered for the dryer. In this example, the energy unaccounted for is negative, which means that either the input energy is lower than it should be, or measurements are inaccurate. Looking at the dryer's Sankey diagram, one can observe that the positive energy unaccounted for is almost equivalent to the negative energy unaccounted for in the firing process. It is therefore likely that the heat recovered from the kiln is actually lower (e.g. inaccurate flow rate). Similar to the UK tunnel kiln, it is possible that too much hot air is sent to the dryer and energy could be saved by reducing the amount of fresh air blown in the kiln and then recovered.

In the Best Practice Sheet, the SEC of the firing process is calculated at 2.8MJ/kg (note: the SEC is based on the number of saleable bricks and not the total number of fired bricks), compared to

best practice tunnel kilns at 0.8MJ/kg based on international benchmarks. The model calculates that, under a conservative scenario, 30% or 0.8MJ/kg of energy savings have been identified, which could bring the kiln's SEC to 2.0MJ/kg. This corresponds to a saving of nearly R6 million per year.

Five areas are highlighted where tested criteria are above expected values for best practice kilns:

- Reducing the moisture content of dried bricks entering the kiln (moisture of 3% vs. 2%)
- Improving combustion efficiency (0.09% of CO in flue gas vs. 0.05%)
- Improving efficiency of heating (SEC of 2.8MJ/kg vs. 0.8MJ/kg)
- Reducing excess air and air ingress levels (excess air of 347% vs. 200%)
- Reducing waste levels (10% vs. 2%)

For each of these five categories a list of opportunities is given for how these savings could be achieved (details are not provided here).

5.4.3. Vertical Shaft Brick Kiln (VSBK) in South Africa

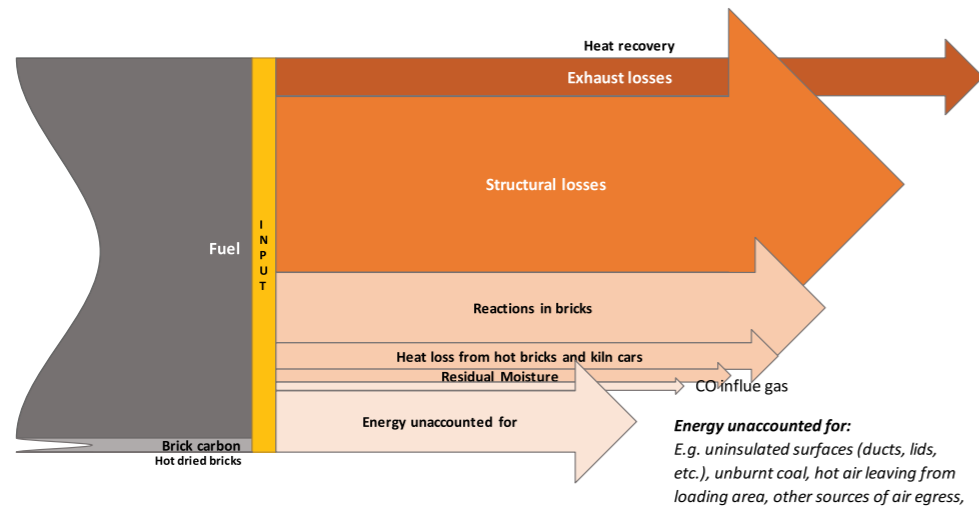
This is a VSBK located in South Africa using coal (nuts and duff) as main fuel. No information is given on the dryer. All required inputs were provided, as well as 83% of recommended inputs and 43% of optional inputs. The outputs for the firing process are presented below (tables and Sankey diagram).

Firing Process

Figure 20: Model results for the firing process of the South African VSBK example displayed in tables and in a Sankey diagram

Energy In	kJ/hour	kJ/kg fired brick	%
Energy from fuels	6,793,533	1,078	96.4%
Energy from brick natural organic carbon content	252,000	40	3.6%
Energy from hot dried bricks and kiln cars	-	-	0.0%
Total	7,045,533	1,118	100%

Energy Out	kJ/hour	kJ/kg fired brick	%
Energy to remove residual moisture	230,891	37	3.3%
Energy for reactions in brick (dehydration, burn-off, vitrification)	1,260,000	200	17.9%
Energy lost in flue gas (exhaust losses)	674,770	107	9.6%
Energy from hot air extraction for heat recovery	-	-	-
Energy lost through kiln walls (structural losses)	3,153,608	501	44.8%
Energy lost in kiln cars	24,696	\$	0.4%
Energy lost from hot fired bricks	457,884	73	6.5%
Energy lost due to CO in flue gas	142,306	23	2.0%
Energy unaccounted for	1,101,378	175	15.6%
Total	7,045,533	1,118	100%



In this example, the exhausts losses are low, which reflects very good use of the heat contained in the exhaust, which is typically the case for VSBK designs. The main area of losses by far is through the kiln walls (note: structural losses are typically hard to estimate accurately and depend largely on the number of measurements made. In this case,

only one average temperature was given, which is insufficient to provide an accurate estimation). In the Best Practice Sheet, the SEC of the firing process is calculated at 1.1MJ/kg, which is similar to best practice plants based on international benchmarks. The model calculates that, under a conservative scenario, 32% or 0.4MJ/kg of energy

savings have been identified, which could bring the kiln's SEC to 0.7MJ/kg. This corresponds to a saving of R0.9 million per year.

Five areas are highlighted where tested criteria are above expected values for best practice kilns:

- Reducing the moisture content of coal (moisture of 2.4% vs. 2%)
- Improving combustion efficiency (0.19% of CO in flue gas vs. 0.05%)

- Reducing excess air and air ingress levels (excess air of 375% vs. 200%)
- Reducing heat loss through the kiln structure (heat loss of 501kJ/kg vs. 200kJ/kg)
- Energy unaccounted for (15.6% vs. 5%)

For each of these five categories a list of opportunities is given for how these savings could be achieved (details are not provided here).



6. Opportunities

6.1. Introduction

In this chapter, best practice opportunities are presented that have the potential to reduce the energy consumption of the kiln and improve quality. We have selected three areas that operators should be continually seeking to improve in their kiln operations:

- Energy consumption;
- Quality;

6.2. List of Best Practices

The list of opportunities below has been produced to assist brick manufacturers to determine the most appropriate recommendations to improve their brick making process.

The list contains 70 energy saving opportunities, which have been selected from a long list of about 150 opportunities from various sources

Environmental impact. The analysis of the best practices below showed that any actions taken to improve energy consumption will also improve the quality of product increasing profits and reduce the environmental impact improving the conditions for workers and the local community.

including energy audits conducted at South African brick yards, manufacturers, suppliers and Carbon Trust. All opportunities were rated for production improvement, energy saving, ease of implementation, cost of implementation, replicability and payback. Based on these criteria, the master list was refined twice to get to the final list of 70 best practices.



Figure 21: Refinement of the best practice list

Using Chapter 5, you may have already determined an approximate heat balance for your kiln to identify where you are losing the largest amount of heat from the kiln. If you have used the thermal energy tool, you should already have identified a subset of best practices from the list below which are most relevant for your plant. In this list, each opportunity has been evaluated to inform brick plant managers on the estimated savings that could be achieved, as well as the estimated investment required and payback period. A number of assumptions were

made to obtain these figures. Therefore, savings, investments and payback periods will be different for every factory, but it should indicate the right scales that can be expected for each opportunity. All opportunities were assessed based on a plant producing 30 million bricks per year.

Most of the measures identified in this section are applicable to all fixed kilns and about half of them are applicable to clamp kilns as well.

This is indicated in the first column.

Kiln Type	Energy Saving Opportunities	Ease of implementation	Business cases based on 30 million bricks/year			
			Estimated energy savings [MJ/year]	Estimated savings [Rand/Year]	Estimated investment [Rand]	Estimated payback [Years]
	1. Improving combustion efficiency					
Clamp	At clamp ignition & start up, ensure fuel is evenly distributed within the firebox as well as the skinkel layers. Use firing channels to ensure efficient combustion for lighting and controlling air flow into the clamp once firing is underway.	easy	3,300,000	121,000	10,000	0.1
Fixed & Clamp	Use of best quality coal available locally with consistent calorific value and consistent particle size, consistent with firing system in place.	easy	4,800,000	176,000	10,000	0.1
Fixed	Add fuel only to the kiln when it will quickly combust, i.e. when red heat can be seen or the temperature is above 800°C.	easy	6,300,000	231,000	50,000	0.2
Fixed	Oil burners: optimise pulse time and droplet size, drops should combust before reaching kiln deck but not prematurely.	moderate	7,500,000	698,000	1,000,000	1.4
Fixed	Carry out ongoing daily check on kiln burners to ensure complete combustion at point of entry.	easy	1,800,000	200,000	0	0.0
Fixed	Measure kiln O ₂ profile and use to adjust the burner air, kiln draft and rapid cooling air to return to optimum setting.	moderate	1,800,000	200,000	200,000	1.0
	2. Improving heating efficiency					
Fixed	Addition of internal fuel (carbon) to minimise the amount of external firing of solid fuel required.	easy	3,000,000	802,000	20,000	0.0
Fixed	Maintaining a steady rise in temperature through the clean and efficient combustion of fuel. Controlled continuous firing of kilns is preferable to over-fuelling the kiln. For example install PLCs & PID controllers on firing equipment.	easy	12,000,000	439,000	250,000	0.6

Fixed & Clamp	Optimisation of setting pattern such that all combustion air can reach all fuel and that hot gases can reach all the bricks.	easy	4,200,000	154,000	20,000	0.1
Fixed	Ensure burner dilution air is maintained to a minimum on dryer burners, use recirculation air instead.	easy	1,800,000	200,000	0	0.0
Fixed	Check that the exhaust fan speed reduces with kiln thermal input i.e. exhaust fan modulates in accordance with the fuel input and closes down during a push, if it doesn't, it means fresh cold air is being pulled into the kiln wasting heat.	moderate	1,800,000	200,000	0	0.0
Fixed & Clamp	Increasing perforation size of extruded bricks consistent with local standards to reduce firing energy requirement and improve air flow through brick setting. (Best practice example increase from 25% to 40%).	difficult	3,000,000	300,000	1,000,000	3.3
Fixed	On TVA/Hoffman type kilns, ensure that a good seal exists in the preheat section and is as air tight as possible so that cold air is not pulled through the bricks by the exhaust fan. (Best practice example assumes 10% of exhaust is from cold air through the preheat heat exchange by 20°C. There is also a power saving.)	easy	1,200,000	130,000	0	0.0
Fixed	Increase recirculation rates in the dryers where possible.	easy	1,005,000	5,106,000	25,000	0.0
Fixed	Use of high velocity recirculation (e.g. cones) in the dryer to improve heat distribution in chamber dryers.	difficult	750,000	84,000	250,000	3.0
3. Reducing excess air and air ingress levels						
Fixed	Reduce exhaust fan speed by 10% to reduce heat loss through exhaust.	easy	3,524,000	372,000	0	0.0
Fixed	Reduce kiln airflow levels by switching off contravac fans and reducing input of low pressure contravac fans where brick exit temperature is already low.	moderate	4,409,000	466,000	0	0.0
Fixed	Reduce excess combustion air by reducing supply pressure or closing damper positions on individual burners.	moderate	5,363,000	343,000	250,000	0.7
Fixed	Improve cooling zone balance by reducing the flow through the exit contravac and the injection cooling by 10% to reduce the egress of hot air from the cooling zone into the firing zone. Use PID controller of air movement fans to maintain a constant pressure in the cooling zone and any heat recovery off take.	easy	2,689,000	284,000	125,000	0.4

Fixed	Use a combustion analyser to measure and minimise excess air levels.	moderate	-	-	-	-
4. Reducing temperature of bricks leaving continuous kilns						
Fixed	Ensure bricks leaving the kiln are cooled to below 100°C and the heat is recovered into the kiln or dryer.	moderate	Savings [MJ/year]	Savings [Rand/year]	Investment [Rand]	Payback [Years]
			6,000,000	650,000	250,000	0.4
5. Reducing heat loss through kiln structure						
Fixed	Insulation of hot air pipework & ductwork. In general, maintain hot air ductwork insulation levels to a minimum of 50mm for temperatures below 200°C and 100mm at higher temperatures.	easy	Savings [MJ/year]	Savings [Rand/year]	Investment [Rand]	Payback [Years]
			720,000	46,000	20,000	0.4
Clamp	Scoving (smearing) the outside walls of a clamp kiln with clay. This is good practice but often not employed where the scale of clamp kilns gets quite large. As the amount of carbon in the bricks is determined before scoving, the practice may not reduce energy usage directly but instead, limit the impact of wind and rain on the brick quality and improve yields.	moderate	6,600,000	204,000	50,000	0.2
Fixed	Ensuring all kiln walls and roofs are maintained in good condition and well insulated.	easy	2,400,000	74,000	50,000	0.7
Fixed	Minimising the time the exhaust damper is left open during new brick setting in a VSBK.	easy	800,000	90,000	0	0.0
Fixed	Fitting exit doors to reduce unwanted additional air on older kilns. Ensure all doors are well sealed and door control management during pushing is effective.	easy	1,200,000	135,000	500,000	3.7
Fixed	Ensure that the stoker pots on permanent roofed kilns are capped to avoid heat losses and are sufficiently numerous to allow an even distribution of fuel into the firing zone.	easy	-	-	-	-
Fixed	Reduce the air flow into and out of the roof cooling space where it exists to reduce heat loss from the kiln.	easy	6,897,000	441,000	250,000	0.6
6. Heat recovery						
Fixed	Using heat exchanger in the exhaust to pre-heat HFO to eliminate the electrical heating system.	moderate	Savings [MJ/year]	Savings [Rand/year]	Investment [Rand]	Payback [Years]
			236,000	47,000	90,000	1.9

Fixed	Install an exhaust heat exchanger to preheat combustion air for tunnel kiln or dryers.	difficult	11,701,000	1,236,000	3,750,000	3.0
Fixed	Use of hot air from the kiln cooling systems as preheated combustion air. For example roof space and kiln car cooling air.	moderate	14,826,000	1,565,000	625,000	0.4
	7. Upgrading kiln technology					
Fixed & Clamp	Replace the current Clamp Kiln with a fixed kiln of some kind (e.g. VSBK, Zig-zag, TVA, Tunnel Kiln etc.).	difficult	252,000,000	7,754,000	18,000,000	2.3
	8. Energy management & measurement					
Fixed & Clamp	Monitor fuel and power consumption in the mine to select the most efficient mining method. With contractors have them purchase their own diesel to encourage energy efficiency in mining operations.	easy	-	-	-	-
Fixed & Clamp	Adoption of Energy Management System (ISO 50 001 or similar).	moderate	-	-	-	-
Fixed & Clamp	Improved metering on fuel consumption.	easy	2,250,000	261,000	380,000	1.5
Fixed	Process optimisation: operate at higher throughputs at the kiln and higher operational equipment effectiveness.	easy	31,158,000	3,810,000	0	0.0
Fixed & Clamp	Rip next mining area at conclusion of mining campaign to allow natural forces (wind, rain & sun) to break down materials before mining.	easy	-	-	-	-
Fixed & Clamp	Use of recent model earth-moving machinery.	moderate	-	-	-	-
Fixed & Clamp	Use of recent model forklifts and optimisation of product movement. Business case with two old machines replaced by one new machine.	moderate	1,530,000	539,000	920,000	1.7

Fixed	Improving quality through temperature measurements: use bullers rings to assess more accurately peak temperature variation within the kiln, use additional permanent or temporary thermocouples. Use these results to reduce temperature variation within preheat, firing & cooling zones.	moderate	-	-	-	-
Fixed	Use a manometer to measure and control draught at the kiln exhaust.	easy	-	-	-	-
	9. Reducing moisture content of dried bricks entering kiln					
Fixed & Clamp	Ensure bricks are fully dried prior (below 2% moisture content) prior to entering the kiln.	easy	4,000,000	450,000	0	0.0
	10. Reducing temperature of kiln cars leaving continuous kilns					
Fixed	Maintaining kiln car seals in optimum condition through planned or condition based maintenance.	moderate	1,800,000	200,000	200000/year	1.0
Fixed	Reduce the thermal mass of kiln car decks using lightweight refractory or fibre.	moderate	15,000,000	1,396,000	3,825,000	2.7
	11. Reducing waste levels by improving the consistency of the raw materials					
Fixed & Clamp	Improvement of raw material mixes by incorporating small quantities of imported materials. Test mixes first in the laboratory prior to incorporation.	moderate	5,550,000	467,000	500,000	1.1
Fixed & Clamp	Improvement of soring practice after mining through stockpiling practices.	moderate	2,850,000	266,000	600,000	2.3
Fixed & Clamp	Obtain a consistent particle size distribution through sieve analysis and adjustment of roller gaps or raw material blend.	moderate	2,175,000	153,000	250,000	1.6
Fixed & Clamp	Ensure a consistent moisture content through proper stockpiling and mixing. Measure moisture content twice daily using direct methods or using penetrometer.	easy	2,175,000	153,000	200,000	1.3

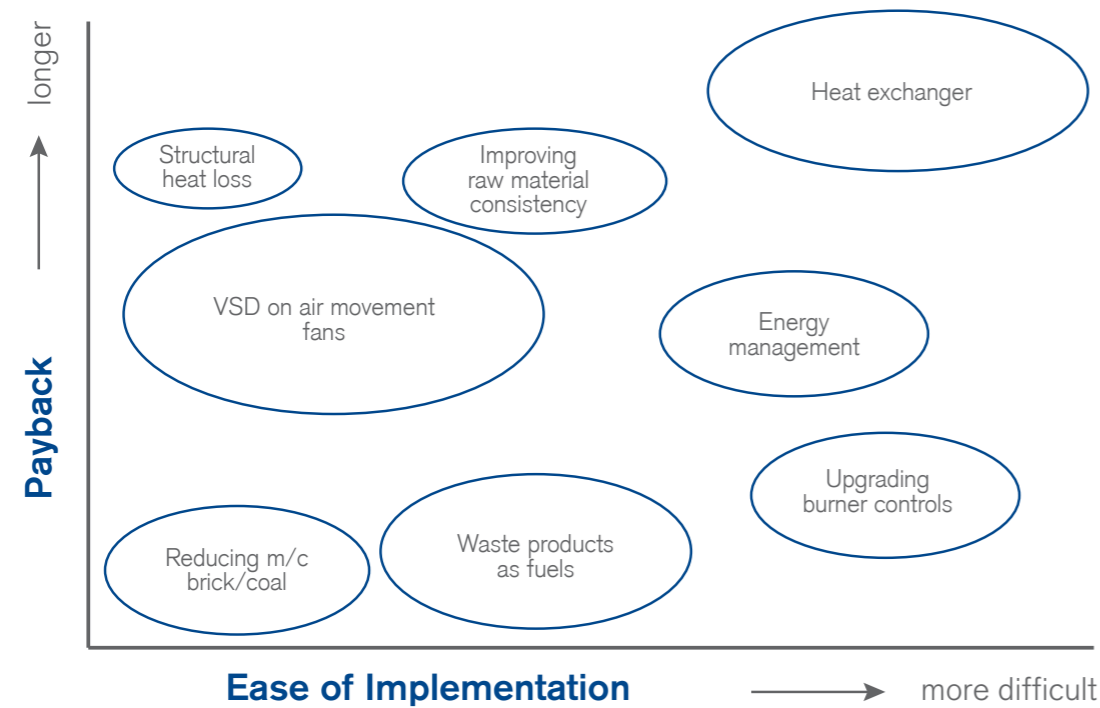
Fixed & Clamp	Scraping of undersize material mix using screens to avoid material unnecessarily going through preparation plant.	moderate	345,000	55,000	300,000	5.5
Fixed & Clamp	Using body additives to improve quality.	easy	2,313,000	45,000	50,000	1.1
Fixed & Clamp	Using body additives to reduce firing temperature.	easy	3,000,000	40,000	150,000	3.8
	12. Low carbon alternative fuels and materials		Savings [MJ/year]	Savings [Rand/year]	Investment [Rand]	Payback [Years]
Fixed & Clamp	Addition of waste products (e.g. sewage sludge, paper pulp) that improve workability/extrudability of the column, benefits include dematerialisation, lower raw material usage, lighter bricks, some fuelling benefit, and lower extrusion amps.	moderate	104,000	1,531,000	500,000	0.3
Fixed & Clamp	Co firing kilns with syngas, biogas or pyrolysis allowing fuel switching to give flexibility.	difficult	0	240,000	2,000,000	8.3
Fixed & Clamp	Open up brick body and reduce fired mass through the addition of lightweight waste materials and biomass material.	moderate	0	1,515,000	500,000	0.3
	13. Power		Savings [MWh/year]	Savings [Rand/year]	Investment [Rand]	Payback [Years]
Fixed	Fan system optimisation (type of fans, de-commission of some fans, etc.).	Easy	-	-	-	-
Fixed	Convert air movement fan motors to variable speed type or fit separate variable speed drive (VSD).	Easy	2,038,000	2,344,000	522,000	0.2
Fixed & Clamp	Power factor correction to reduce maximum demand charges and resistance losses.	Easy	-	-	-	-
Fixed & Clamp	Tariff optimisation through shifting operations outside of peak hours, especially during the high demand season.	Easy	-	-	-	-

Fixed & Clamp	Maximum demand management through implementation of a real time measurement and monitoring system to control maximum demand charges.	Easy	0	78,000	15,000	0.2
Fixed & Clamp	Automated & phased switch off of plant when production ceases.	Easy	600,000	690,000	200,000	0.3
Fixed & Clamp	Motor efficiency retrofits on less efficiency motors, for example from IEE1 to IEE3.	Easy	74,000	86,000	256,000	3.0
Fixed & Clamp	Replacing oversized motors with correct specification.	Easy	341,000	393,000	0	0.0
Fixed & Clamp	Replace existing standard solid V-drive belts with cogged V-belts to increase power transfer efficiency & reduce slipping.	Easy	94,000	109,000	60,000	0.6
Fixed & Clamp	Optimising compressed air system efficiency.	Easy	250,000	288,000	0	0.0
Fixed & Clamp	Voltage control on crushing plant.	Easy	250,000	288,000	165,000	0.6
Fixed & Clamp	Rationalise transformers.	Easy	111,000	128,000	30,000	0.2
Fixed & Clamp	Upgrading existing lighting system with energy efficient units and controls (e.g. fluorescent lights, electronic control gear, low power fluorescent types, LEDs, occupancy sensors, etc.). Example: upgrade the existing lighting fixtures with lower wattage fixtures.	Easy	125,000	144,000	52,000	0.4
Fixed & Clamp	Making use of daylight harvesting through the use of clear roof sheeting.	Easy	7,000	9,000	4,000	0.4
Fixed & Clamp	HVAC control optimisation.	Easy	16,000	19,000	14,000	0.7
Fixed & Clamp	Domestic hot water optimisation (e.g. replacing electric geyser with a hybrid solar water heater).	Easy	122,000	141,000	60,000	0.4

6.3. Business Cases

One way to assess the opportunities is to classify them in a graph based on their payback period and ease of implementation, where the size of the opportunity is proportional to the size of the circle.

Figure 22: Classification of a subset of opportunities according to their payback period and ease of implementation



Based on this rating method and their relevance for the South African market, 10 best practices were chosen for detailed business cases. The choice was confirmed during two workshops organised in Pretoria and Cape Town, where participants selected their top opportunities. These 10 opportunities ranked amongst the favourite ones (details on the workshops are provided in the appendices).

1. Replace the current clamp kiln with a fixed kiln (e.g. 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. Reduction of the 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

6.3.1. Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln, etc.)

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln, etc.)

Development

Clamp kilns 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.). The choice of kiln is subjective and dependant on many factors such as the projected output, the type of product to be produced (e.g. face bricks or plaster bricks) and the availability of skilled staff.



A typical South African clamp kiln



Tunnel kiln alternative



VSBK Alternative

Description

Switching to a new kiln type has the potential to drop the energy consumption from clamp kiln typical values of 4 – 5MJ/kg of fired ware, down to as low as <1.0MJ/kg of fired ware. Furthermore, not only will the energy performance improve dramatically, increased yields and reduced waste can also be expected. A recent successful example is the adoption of VSBK technology in South Africa which has proven itself to be possibly the most energy-efficient type of kiln available. Other alternatives which have had recent interest in South Africa includes the tunnel kiln and the Zig-zag kiln, both of which offer a drying capacity that the VSBK currently does not.

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln)

Technology maturity and need for support

Approximately 60% of South Africa's brick production is sourced from clamp operators. Many of these are family-owned businesses which have been producing bricks in clamp kiln for up to three generations. Hence, their current operational methodology is entrenched.

Notwithstanding the above, tunnel kilns have been operating in South Africa since the 1960s. Transverse arch kilns have a similarly lengthy history and recently, VSBKs have gained traction. A type of Zig-Zag kiln also operated continuously for almost 30 years, although widespread adoption of this style of kiln has yet to occur.

Traditionally, tunnel kiln technology was the reserve of European suppliers such as Keller, Lingl, Direxa (Ceric) and Hässler. Lesser known or now defunct marques such as Walter and Dillers Kilns amongst others, also built tunnel kilns in South Africa but recently, Chinese technology has made some inroads into the South African tunnel kiln market. Should tunnel kiln technology be chosen, there are certainly a number of capable suppliers available depending on the customer's requirements.

VSBK is supported in South Africa by a local entrepreneur who has gained considerable experience with the technology over a short period. Initial uptake was sluggish, but recently, a number of new VSBK projects have broken ground. Each new project is a learning experience with this technology in South Africa and as uptake grows, further improvements are anticipated which will benefit future customers. Conversely, as the technology becomes more popular and improves, future customers are likely to pay more than the early adopters.

Recently, Habla Zig-Zag Kilns International (HZZKI) commenced building a proprietary Zig-Zag kiln in South Africa. Although other Zig-Zag kilns have been built in the past, Habla Zig-Zag claim their kiln design to be superior. A Russian company, Stromtechnica, also visited South Africa recently. Although their kiln design - an intermittent chamber kiln with removable roofs - appears promising, the company has yet to gain traction in South Africa. Notwithstanding, it is likely that there will soon be other proven alternative technologies to clamp kilns available for the consideration of South African brick manufacturers.

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln)

Possible project approach

The first step towards an alternative kiln technology is recognising the need for change. Although clamp kiln methodology may have been entrenched over generations, change agents such as carbon taxes, rising fuel costs and environmental charges are likely to enforce change. The labour landscape in South Africa is also changing and it is unlikely that clamp kiln operation will remain sustainable in South Africa.

The projected output, type of product, the availability of skilled staff and the need for mechanised drying are important factors to consider in choosing an applicable technology. Furthermore, clamp kiln operators will already have a milling and extrusion operation in place – there is no benefit in installing a high technology kiln when the rest of the plant is not up to a similar level. Upgrading dematerialisation and extrusion may also be necessary.

Current thinking suggests that tunnel kilns are best suited to high outputs and the highest quality of product. Tunnel kilns also generally provide hot air for drying, however tunnel kiln technology is likely to work out the most expensive, both from a capital and operational cost perspective.

VSBK technology has proven effective for a regional manufacturer. Although the technology is scalable, each VSBK shaft requires operator care on a 24/7 basis, which is a concern for higher volume producers. Additionally, the manual handling and kiln environment of VSBKs pose limitations to the level of product that a VSBK can produce. However, these limitations are not insurmountable and the cost of VSBK technology is certainly attractive. Currently, VSBK technology does not offer mechanised drying - a drawback in areas with significant seasonal weather patterns.

In most cases, construction of a fixed kiln will require external support. A variety of suppliers is available if the manufacturer is clear on his/her technology choice, but in the face of bewildering technology choices, the CBA (or some of its members) and the EECEB may also provide guidance.

Once a technology choice has been made, it is useful to obtain quotations from more than one potential supplier. Each supplier will bring their own solution, allowing the manufacturer to consider which may be best suited to their operation. Once the solution is chosen, various service providers such as project managers, engineers and contractors will usually be needed to take the project to fruition as many brick manufacturers do not have all the in-house expertise required. Often, it is beneficial for a manufacturer to focus on maintaining the health of the existing business while the kiln technology upgrade proceeds rather than focussing entirely on the project at the expense of the regular business. Resources such as the CBA and EECEB may be able to provide suggestions as to experienced service providers who can assist manufacturers.

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln)





Estimated project cost	<p>Cost to deploy: Varies</p> <p>All technology types will require regulatory approval of some kind. Depending on the site and the complexity involved, an environmental impact assessment may add a cost of up to R250,000 to a firing technology upgrade project.</p> <p>A tunnel kiln with a dryer capable of producing about 30 million bricks per annum is likely to cost from R30 million upwards, depending on the technology supplier. Note that this cost represents the lower end of the spectrum. A tunnel kiln with a dryer and kiln cars could be a lot more expensive.</p> <p>An 18-shaft VSBK plant capable of producing about 30 million bricks per annum is likely to cost around R18 million. Note that this figure represents the lower end of the spectrum.</p> <p>Projected costs on the Habla Zig-Zag Kiln are currently unknown, and costings are also not available for other kilns such as the Stromtechnica design. As both designs are currently aimed at lower outputs, costs will need to be scaled for comparison against the above.</p> <p>Time to deploy: Varies</p> <p>Construction time on a tunnel kiln could be as long as nine months. A VSBK project or another type of kiln could be similar or less, but in all cases, the time to deploy will be subject to regulatory approval. A clamp kiln manufacturer starting from scratch may face a wait of up to a year before the requisite regulatory approval is received and the project may legally proceed.</p>

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln)

Saving	<p>For the purposes of cost comparison, a VSBK is the fairest direct comparison against a clamp kiln as neither technology is currently able to dry bricks. Additionally, tunnel kiln operating costs and fuel consumption can vary quite widely depending on the products made. Hence, the focus of this section is the VSBK.</p> <p>If a clamp yard producing 30 million bricks per annum is upgraded to VSBKs of a similar output, the specific energy consumption of the kiln is likely to drop from around 11GJ/1000 BE to about 2.6GJ/1000 BE. Please note that the energy consumption of clamp kilns varies quite widely – some clamp kilns consume significantly more energy than 11GJ/1000 BE. Additionally, it is assumed that the adoption of VSBK technology will include the adoption of perforated bricks – a fired weight decrease from 3.1kg to 2.6kg per brick has been included in the calculations.</p> <p>30 million bricks per annum @ 11GJ/1000 BE = 330,000GJ per annum 30 million bricks per annum @ 2.6GJ/1000 BE = 78,000GJ per annum Energy saving is 330,000 – 78,000 = 252,000GJ per annum</p> <p>The CO₂ saving potential is 24,700 / t CO₂ per annum.</p> <p>Coal, the most common kiln fuel source, is generally more expensive in coastal regions than inland. Assuming a fuel cost at the coast of R1,310/t and R800/t inland, annual cost savings are estimated at:</p> <p>Coastal – R12.7 million Inland – R7.75 million</p>
	Payback
Site Energy/CO₂ saving per site	<p>Site energy saving: 252,000GJ per annum Site CO₂ saving: 24,700t CO₂ per annum</p>

Replace the current clamp kiln with a fixed kiln (e.g. VSBK, Tunnel Kiln)	
Sector Energy/CO₂ saving potential	<p>Currently, 60 – 70% of brick manufacturing plants in South Africa use clamp technology. The cumulative output of all the clamp kilns in South Africa varies significantly according to demand but it can be reasonably assumed that a minimum of 1 billion bricks are produced annually in South African clamp kilns.</p> <p>50% shift to VSBK technology Sector energy saving: 4,200,000GJ per annum Sector CO₂ saving: 412,000t CO₂ per annum</p> <p>100% shift to VSBK technology Sector energy saving: 8,400,000GJ per annum Sector CO₂ saving: 824,000t CO₂ per annum</p> <p>It is unlikely that all clamp producers will shift towards VSBK technology – scalability issues and the lack of a mechanised drying options are the chief concerns. Other kiln technologies will also replace clamp kilns but significantly, if international trends are mirrored in South Africa, it is likely that output from brick producers who do not move forward and change will eventually be lost to alternative building products.</p>
Market penetration	The South African brick industry has a history of resisting change. Should a climate conducive to change be created by the correct blend of incentives and punitive measures, major change is possible within 20 years.
Barriers to adoption	<ul style="list-style-type: none"> i. Business confidence (concerns about consistency and volatility) ii. Cost and availability of finance iii. Entrenched operational methodology iv. Relatively low fuel costs in inland areas v. Concerns on scalability of kiln technology vi. Lax environmental legislation
Risks to clamp kilns	<ul style="list-style-type: none"> i. Increasing environmental compliance / legislation requirements ii. Carbon tax iii. Market volatility iv. Labour volatility v. Alternative building materials

6.3.2. Addition of Waste Products (e.g. sewerage sludge, paper pulp)





Addition of waste products (e.g. sewerage sludge, paper pulp)	
Development	<p>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. Depending on the nature of the waste product, potential benefits include:</p> <ul style="list-style-type: none"> • Dematerialisation, i.e. lower raw material usage
Description	 <p>Waste addition can replace up to 15% of regular raw materials</p>
	<ul style="list-style-type: none"> • Reduction in requirement for process water (many wastes contain significant amounts of water) • Improvement in workability / extrudability of the column, thus requiring lower energy for the extrusion process and sometimes obviating the need for additional die lubrication
	 <p>Extruder Amps can be lowered and die lube can be changed to water or even turned off</p>
	<ul style="list-style-type: none"> • Fuelling benefits  <p>Depending on the waste, fuel swaps of up to 100% of the regular fuel are known</p>
	<ul style="list-style-type: none"> • Production of lighter bricks  <p>Lighter bricks reduces transport costs and can significantly enlarge a factory's footprint</p>
	<p>Clearly, various waste products can have wide-ranging positive effects for brick manufacturers and for this reason, it is difficult to cover them all.</p>

Addition of waste products (e.g. sewerage sludge, paper pulp)	
Technology maturity and need for support	<p>The use of waste products is not widespread in South Africa. This is probably due mostly to the lack of useful waste products or possibly the communication gap between producers of such waste products and brick manufacturers. On a secondary level, there may be some legislative or technical hurdles to overcome which dissuade brick manufacturers from considering waste streams. The recent introduction of the requirement for a waste licence is a significant hurdle for brick manufacturers who are using / want to use waste products in their processes.</p> <p>Notwithstanding the above hurdles, the requirement for new technology is generally limited - meaning that minimal specialist support is needed. In most cases, only basic infrastructure such as box feeders and, or bundled storage areas are required making this opportunity accessible to most brick manufacturers. The proviso is that a suitable waste product stream needs to be available. Although waste product streams seem to have better availability in the vicinity of metropolitan areas, regional producers close to agricultural or mineral processing facilities may also have access to useful waste streams.</p>
Possible project approach	<p>The CBA (or some of its members) and the EECB may provide some guidance to brick manufacturers who wish to consider using waste streams. Government initiatives are also useful resources – the Western Cape has a programme known as the Western Cape Industrial Symbiosis Programme (WISP), which specifically aims to assist its members, especially SMEs, fill gaps in experience or provide additional resourcing towards identifying and implementing resource, waste and energy efficient practices.</p> <p>On a practical level, significant trials can be done in laboratories and test kilns before factory trials need proceed. In this regard, there are a number of professional service providers in South Africa and abroad who are able to assist brick manufacturers and provide external technical expertise.</p> <p>Should a case prove promising, manufacturers require a waste licence to commence brick production using a waste product stream as an additive. In most cases, a full environmental impact assessment (EIA) is required in order to obtain a waste licence – it is necessary that this be carried out by external, independent professionals. Factors surrounding the site, the process and the waste stream can influence the programme and cost significantly but a full year from start to finish is about normal.</p>

Addition of waste products (e.g. sewerage sludge, paper pulp)	
Estimated project cost	<p>Cost to deploy: R 500,000</p> <p>Approximately R200,000 of the above amount may be required for the EIA. The remainder is the estimated amount required for a straightforward box feeder and delivery conveyor belt.</p> <p>Time to deploy: 1 year</p>
Saving	<p>Due to the wide-ranging possibilities out there, it is not possible to cover all potential waste streams. This analysis will therefore focus on one particular waste stream– the usage of sludge from a waste water treatment works.</p> <p>Assumptions:</p> <ul style="list-style-type: none"> 30 million bricks produced per annum Raw material cost R40/1000BE 8% of raw material by volume replaced by sludge Sludge calorific value of 16MJ/kg Sludge water content of approximately 70% Average drop in extruder current 15A for 9.5hrs per day Firing energy requirement 5.0GJ/1000BE Fuel cost approximately R4.00/kg for fuel with 43MJ/kg energy content Electricity cost R0.72/kWh Energy saving calculated from drop in extrusion current only Cost saving calculated from reduction in fuel cost and minor electricity saving <p>Savings</p> <ul style="list-style-type: none"> Energy saving: 103,000 MJ per annum Cost saving: R2 Million per annum The CO₂ saving potential is 27t per annum (at 0.94kg CO₂ per kWh electricity in SA)
Payback	<p>Based on the sludge example above, payback can be calculated as follows:</p> <p>1 year, 3 months (assuming EIA takes 1 year to complete)</p>
Site Energy/CO2 saving per site	<p>Site energy saving: 103,000 MJ per annum</p> <p>Site CO₂ saving: 27tCO₂ per annum</p>

Addition of waste products (e.g. sewerage sludge, paper pulp)	
Sector Energy/ CO2 saving potential	<p>Replicability across the sector is limited by the availability of waste streams. Assuming that 70 of the approximately 90 CBA manufacturing sites may be suitable for the use of waste streams, an upper figure of 20 sites is estimated as having the potential to use waste streams in brick manufacturing. Furthermore, each waste stream may have different energy saving characteristics, so assumptions made across the sector should be viewed with this understanding.</p> <p>Sector energy saving: 2,060GJ per annum Sector CO₂ saving: 540t CO₂ per annum</p>
Market penetration	<p>If all 20 potential sites begin the process of identifying and testing various waste products immediately, a period of three – five years is estimated for uptake of this opportunity. Following any initial uptake, new developments will continually create additional opportunities from time to time.</p>
Barriers to adoption	<ul style="list-style-type: none"> i. Availability of waste products near the plant ii. Environmental compliance / legislation iii. Security of tenure over the waste stream iv. Cost of the additional infrastructure needed v. Clamp yards may struggle when waste stream is inconsistent vi. Technical difficulties
Risks	<ul style="list-style-type: none"> i. Some waste products can degrade the bricks produced ii. Increasing environmental compliance / legislation requirements iii. Clamp yards have long lead times and require significant investment in work in progress – this discourages trials iv. Some wastes may produce dangerous by-products v. Dangers to staff with manual handling

6.3.3. Controlled and Efficient Combustion of Fuel

Controlled and efficient combustion of fuel	
<i>Development</i>	
Description	<p>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.</p>
	 <p>Chain-driven coal duff feeders that replaced manual feeding</p>
	 <p>Temperature PID controller – as long as the green number < the red number, fuel is added</p>
	 <p>Tunnel kiln heavy furnace oil burner installation – burners are simple and inefficient and control very broad</p>
	 <p>Computerised tunnel kiln firing control system</p>
<p>Additional benefits anticipated include improved yield and reduced waste. A burner system that is erratic or inconsistent may over-fire and clinker in some places, while leaving other areas under-burnt.</p>	

Controlled and efficient combustion of fuel	
Technology maturity and need for support	<p>Existing installations in South Africa range from those with manual fuel addition through to high-tech automated systems. Although best practice installations are usually proprietary systems from experienced European suppliers such as Keller, Lingl, Direxa (Ceric), Beralmar, High-Tech etc., locally sourced equipment can also present a significant step-up from manual feeding.</p> <p>With regard to local sourcing, the CBA (or some of its members) and the EECB may provide some guidance to brick manufacturers wishing to upgrade their systems. In addition, there are numerous South African mechanical and electrical contractors capable of providing significant support in this arena.</p>
Possible project approach	<p>The level of investment and modifications required on the kiln is highly dependent on the kiln and existing automation. A kiln in the open with minimal electrical installation may necessitate more work and investment than a kiln that is already under a roof. Conversely, a tunnel kiln already fitted with a basic automatic firing system may require a significant investment to upgrade the system to the next level.</p> <p>In many cases, internal expertise should recognise the need for the investment. However, the finer details of the proposed project are best worked out with external service providers such as proprietary firing system suppliers or mechanical and electrical contractors.</p>
Estimated project cost	<p>Cost to deploy: R 250,000 – R1,000,000 (varies according to existing level of automation)</p> <p>Time to deploy: 3 – 9 months (varies according to existing level of automation)</p>
Saving	<p>Potential savings are dependent on the type of fuel used and the initial level of kiln efficiency. The type of fuel used is further dependent on the location of the plant – if coal is the fuel source, coastal areas generally pay more than inland areas. For calculation purposes, controlled and efficient combustion is estimated to improve fuel consumption by an average of 5%. The anticipated additional benefits of improved yields and reduced waste are omitted from the calculation.</p> <p>Coal firing Assumptions: 30 million bricks produced per annum Main firing fuel is B grade nuts with energy content 26MJ/kg Coastal energy cost: R1,460/t Inland energy cost: R950/t Initial firing energy requirement 8.0GJ/1000BE 5% Energy saving due to controlled and efficient combustion</p>

Controlled and efficient combustion of fuel	
Saving continued	<p>Savings: Energy saving of 12,000GJ per annum Coastal – R670,000 per annum Inland – R440,000 per annum</p> <p>HFO firing Assumptions: 30 million bricks produced per annum Main firing fuel is HFO with energy content 43MJ/kg HFO cost R4/kg Initial firing energy requirement 5GJ/1000BE 5% Energy saving due to controlled and efficient combustion</p> <p>Savings Energy saving: 7,500GJ per annum Cost saving: R700,000 per annum</p>
Payback	<p>A range is provided due to the potential range of project costs.</p> <p>Project cost R250,000 Coal firing Coastal – 4 months Inland – 7 months</p> <p>Project cost R1 Million Coal firing Coastal – 1.5 years Inland – 2.3 years HFO firing – 1.4 years</p>
Site Energy/CO₂ saving per site	<p>Site energy saving: 7,500 – 12,000GJ per annum Site CO₂ saving for coal: 735 to 1,180t CO₂ per annum Site CO₂ saving for HFO: 540 to 860t CO₂ per annum</p>

Controlled and efficient combustion of fuel

Sector Energy/CO₂ saving potential

Replicability across the sector is limited to the number of fixed kilns in South Africa currently estimated at 30% of the sites or about 25 plants. Of these sites, it is anticipated that about 10 sites may not benefit greatly from investment into controlled and efficient combustion suggesting that 15 sites may have potential for this energy saving opportunity. As each site has a different output capacity, the lower value of 7,500GJ per annum is applied to 15 sites.

Sector energy saving: 112,500GJ per annum
Sector CO₂ saving: 11,000t CO₂ per annum (coal)

Market penetration

The potential for energy saving at the above mentioned 15 sites is real as are the potential cost savings and payback. Nevertheless, a combination of factors (see barriers to adoption) have tended to minimise investment in this area. Should business confidence improve and a climate conducive to change be created by the correct blend of incentives and punitive measures, it is estimated that five of the 15 sites may upgrade firing systems within five years with a further four sites upgrading within 10 years.

Following any initial uptake, new developments will create additional opportunities from time to time.

- Barriers to adoption**
- i. Business confidence (concerns about consistency and volatility)
 - ii. Cost and availability of finance
 - iii. Relatively low fuel costs in inland areas
 - iv. Doubts over potential improvement
 - v. Entrenched operational methodology
 - vi. Lax environmental legislation
 - vii. Technical difficulties

- Risks**
- i. Continued availability of same fuel
 - ii. Increasing environmental compliance / legislation requirements
 - iii. Carbon tax
 - iv. Market volatility
 - v. Labour volatility
 - vi. Alternative building materials

6.3.4. Use of Recent Model Mobile Plant and Movement Optimisation to Reduce Energy Use

Use of recent model mobile plant and movement optimisation to reduce energy use

Development

When it comes to replacing or maintaining mobile plant, brick manufacturers face a difficult decision. Is it better to maintain old machinery that is possibly owned outright, or replace it with new plant that may need to be financed?

From an energy efficiency point of view, current generation mobile plant can use as little as 50% of the fuel needed by older generation plant. Additionally, the capacity of plant has improved to such a degree that a new machine with a similar footprint to an old machine is now capable of doing almost twice the duty. For example, a new 5t rough terrain forklift can fulfil the duty of two old generation rough terrain forklifts, each with a lifting capacity of around 3t.



Older forklift with open seating and 2 tines



Newer generation forklifts with enclosed cabs and 3m

Description

As a general rule, most new generation mobile plants are supplied with an enclosed cab which not only provides all-weather operator comfort but also significantly improves operator and pedestrian safety. In some cases, a single machine can fulfil the duty of two older machines, meaning that the second plant operator can be redeployed. New generation machinery is generally quieter and hence, reduces the need for hearing protection when operated inside.



Lastly, it is likely that the best return in a brick manufacturing operation is achieved when the manufacturer is able to concentrate on making bricks. Notwithstanding the downtime potential, the maintenance of older mobile plant can demand significant attention, and time that can be more fruitfully spent elsewhere. The shortage of good artisans - such as diesel mechanics - in some areas exacerbates this

Use of recent model mobile plant and movement optimisation to reduce energy use	
Technology maturity and need for support	<p>The use of newer mobile plant is quite varied across South African brick manufacturers. At some larger plants, one may see a fleet of as many as 23 recent model forklifts, whereas similar operations nearby maintain their fleet of older machines. Similar contrasts can be seen with front-end loaders and other earth moving machinery – front-end loaders from the 1980s are not uncommon.</p> <p>For those manufacturers considering new plant, there are numerous mobile plant brands active in the brick manufacturing arena, represented by a number of different companies. In no particular order, these brands include Manitou, Volvo, Bell, Linde, Cat and Komatsu, amongst numerous others. Some brands are stronger in particular areas or particular types of equipment and brick manufacturers are encouraged to shop around for a solution tailored to their needs.</p>
Possible project approach	<p>Recognising the need to update mobile plant is never easy. While new machinery is less likely to experience serious issues than old equipment, older machinery that is adequately maintained is not always in need of renewal. The establishment of clear cut policies with regards to mobile plant renewal is therefore not straightforward and involves site-specific consideration, including the required duty and the potential costs of an unexpected failure. The availability of good artisans is another important consideration.</p> <p>Establishing the real cost of maintaining old equipment is a useful step. Although funds spent on parts and service providers are easy to track, management and staff time spent on machinery maintenance is much harder to account for.</p> <p>With an effective management system functioning, mobile plant suppliers, the CBA (or some of its members / associates) and the EECB may provide some ideas to brick manufacturers considering plant renewal. External ideas may be useful as brick manufacturers who are used to doing things in a certain way may not be aware that there are other, more cost effective ways of achieving the same result. In some cases, movement studies can be useful towards determining whether there is scope to replace two or more smaller capacity machines with fewer, larger capacity plant.</p>
Estimated project cost	<p>Cost to deploy: Varies</p> <p>Examples:</p> <ul style="list-style-type: none"> 5t rough terrain forklift: R920,000 or hire purchase for R22,000 per month over 60 months – dealer maintenance costs R12,612 per month dependent on duty Front-end loader with standard 2.3m³ bucket and 95kN breakout force: R1,68 Million – dealer maintenance costs around R23/hr dependent on duty <p>Time to deploy: From immediately to a few months</p>

Use of recent model mobile plant and movement optimisation to reduce energy use	
Saving	<p>Due to the wide-ranging possibilities out there, it is not possible to cover all potential uses of mobile plant in the brick manufacturing sector. Hence, this analysis will focus on an actual case where a brick manufacturer chose to replace two older model rough terrain forklifts with a single, larger capacity machine.</p> <p>Assumptions:</p> <p>Old machines (owned outright) Approximate value: R150,000 Holding cost of capital: 10% Annual ownership costs: R15,000 Monthly maintenance costs: R5,000 Capacity: ±3t (i.e. enough for 1 pallet of green bricks) Monthly operating hours: 400 Diesel usage: 6l/hr Litres of diesel per month: 2,400l Driver costs: R7,500 per month or R90,000 per annum</p> <p>New machines (bought on hire purchase) Monthly payment: R22,000 Annual ownership costs: R264,000 Monthly maintenance costs: R10,000 Capacity: 5t (i.e. enough for 2 pallets of green bricks) Monthly operating hours: 400 Diesel usage: 3.5l/hr Litres of diesel per month: 1,400l Driver costs: R7,500 per month or R90,000 per annum Diesel price: R11/l</p> <p>2 x old machines replaced by 1 x new machine</p> <p>Energy saving of 1,530GJ per annum (annual diesel saving of 40,800l)</p> <p>Cost saving $(40,800l \times R11/l) + (R30,000 - R264,000) + R90,000 = \mathbf{R304,800 \text{ per annum}}$</p> <p>Note on cost saving: For the purposes of simplicity, depreciation and tax have been omitted. A capital incentive tax allowance of 40% of the value of the new equipment can be used to reduce company tax payable in the first year and defer tax thereafter. Hence, a company's financial structure and profitability may act towards enhancing the cost saving given above. Brick manufacturers are encouraged to obtain professional accounting advice in this regard.</p> <p>The CO₂ saving potential is 110t per annum.</p>

Use of recent model mobile plant and movement optimisation to reduce energy use	
Payback	Immediate in above example, but will vary
Site Energy/CO₂ saving per site	<p>Site energy saving will vary depending on machinery and replicability.</p> <p>Assuming above operation replaces four old forklifts with two newer machines, site energy saving is 3,060 GJ per annum.</p> <p>Site CO₂ saving will vary depending on machinery and replicability</p> <p>Assuming above operation replaces four old forklifts with two newer machines, site CO₂ saving potential is 220 t per annum.</p>
Sector Energy/CO₂ saving potential	<p>The forklift example above is an ideal combination of hours, terrain and duty, used to illustrate the point. Not every site will offer savings potential at this level and in many cases, significant energy savings may not be accompanied by significant cost savings, thereby limiting the uptake. On this basis, it is assumed that 50% of brick manufacturing sites (around 43 sites) may offer energy saving opportunities of 50% of the level illustrated in the above example (1,500GJ per annum).</p> <p>Sector energy saving: 64,500GJ per annum</p> <p>Sector CO₂ saving: 4,600t per annum</p>
Market penetration	<p>Company policies regarding mobile plant renewal will always differ. Different attitudes towards risk, levels of business confidence and the availability of skilled artisans will see some firms updating their plant regularly, while others choose to maintain what they already have. A further complication is that mobile plant is improving all the time and the best performance in 2015 may only be average in a few years' time.</p> <p>Based on the above, it is suggested that 50% of brick manufacturers may work towards a mobile plant renewal system or policy within five years. During the same period, approximately half may act on their policy towards evaluating their mobile plant duties and consider mobile plant renewal. The remainder are likely to continue mobile plant renewal on an ad hoc basis.</p>
Barriers to adoption	<ul style="list-style-type: none"> • Business confidence (concerns about consistency and volatility) • Cost and availability of finance • Complex tax laws • Lack of mobile plant management systems and policies • Entrenched existing operational methodology • Doubts over potential improvement • Lax environmental legislation
Risks	<ul style="list-style-type: none"> • Availability of skilled artisans • Emergence of new generation, more efficient mobile plant • Business volatility • Labour volatility • Government legislation and changes in tax law

6.3.5. Increase Perforation Size of Extruded Bricks

Increase perforation size of extruded bricks	
<i>Development</i>	<p>As long as the percentage of perforations in a brick is below 25%, the brick is deemed to be a solid masonry product. The potential to use 25% less raw material - with commensurate savings in energy - is appealing. Nonetheless, it is estimated that more than 60% of South Africa's clay bricks are made without any perforations.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Solid bricks</p> </div> <div style="text-align: center;">  <p>Perforated bricks</p> </div> </div> <p>In the clay brick manufacturing process, perforated bricks use less raw material, meaning mine life is extended and raw material costs are reduced. As less raw material is needed, less energy is also consumed in clay preparation and there is less wear on the machinery for the same brick output. In the extrusion process, the reduced volume through the extruder for perforated products is balanced by the higher extrusion pressures that may be needed for perforated products.</p>
Description	<p>Due to the reduced volume, forming and shaping requires less water and commensurately, less heat and air flow are required for drying. If setting density is maintained in the kiln, a greater volume of bricks can be fired in the same kiln using less energy per brick than bricks made without perforations. Outside the factory building, any manual handling is improved due to the reduced weight of perforated products and mobile plant such as forklifts and trucks are also able to handle more of the product at a time with reduced energy consumption per brick.</p> <p>In clamp yards specifically, perforated products dried in the open may dry faster. Clamp kilns may also fire faster due to the reduced mass, thereby improving the cycle time, reducing work in progress and saving cost. The additional circulation in clamp kilns provided by perforations has also been known to improve product consistency.</p> <p>The energy and cost implications of the above are clear. Less obvious is the shift in building trends towards products regarded as "greener" and more sustainable. If international trends are mirrored in South Africa, brick producers who choose to manufacture non-perforated products will eventually find themselves on the losing side of these trends, with part of the market share moving to alternative building materials.</p>





Increase perforation size of extruded bricks	
Technology maturity and need for support	<p>It is estimated that >30% of the bricks manufactured in South Africa are perforated. Hence, there is much experience to draw from, and manufacturers have a multitude of sources from which advice can be sought.</p> <p>Brick Management and Manufacturing Supplies (BMMS) are the South African agents for JC Steele and Händle and are therefore well-versed in the equipment needed for perforated extrusion. South Africa is predominantly a stiff extrusion market and while there are other companies that manufacture dies specifically for stiff extrusion, Reymond Dies, a stiff extrusion die specialist, is possibly the best known alternative.</p> <p>In the semi-stiff extrusion space, a number of European suppliers can provide support. Braun, a well-known German die manufacturer has recently come under the Händle umbrella. Other brands active in this area include - amongst others - Bongiani Stampi and Tecnofiliere, who provide brick manufacturers with a number of avenues to follow for support.</p>
Possible project approach	<p>The first step towards perforated extrusion is recognising the need for change. Although solid extrusion methodology may have been entrenched over generations, change agents such as carbon taxes, rising fuel costs and environmental charges are eventually likely to enforce a shift. Where manual handling is involved, the difference in weight between solid and perforated bricks may also drive the change process. A handful of clamp kiln manufacturers have already made the change successfully.</p> <p>If a manufacturer has generally only made solid bricks, it is likely that some external advice on the finer points of perforated extrusion may be needed. In many cases, a grinding regime that is sufficient for solid bricks may prove inadequate for perforated extrusion, thereby requiring significant effort before the extruder. Local suppliers may be able to advise manufacturers or alternatively, the CBA (or some of its members) and the EECB may provide guidance.</p> <p>In most cases, a step by step approach is advocated, whereby small scale trials are conducted and evaluated. An imbalanced die leading to invisible drying cracking may make it appear as if perforated bricks do not fire effectively in a clamp kiln, whereas the real problem may lie elsewhere. If green strength is an issue, manual handling may exacerbate issues.</p>

Increase perforation size of extruded bricks	
Estimated project cost	<p>Cost to deploy: Starting from R40,000, but could vary greatly (Cost can reach R500,000 per extruder)</p> <p>Should a manufacturer already have a suitable crushing regime, the initial outlay could be limited to a die base capable of anchoring a bridge, along with said bridge, cores and possibly a shaper cap. Manufacturers wanting to trial such a system may be able to borrow this equipment at minimal expense.</p> <p>Should the existing crushing system be insufficient, additional machinery may be needed to obtain the required throughput at the correct raw material particle size, to shift from solid to perforated brick extrusion. This could have significant cost implications.</p> <p>Time to deploy: 1 year, but could vary</p> <p>It is suggested that small scale trials be carried out over time. Due to the time taken for open air drying and clamp firing, initial trials could take more than three months and prove unsuccessful. Similarly, seasonal variations could introduce other variables that require time to resolve. If there are brick plants in South Africa with mechanised drying and fixed kilns that are not producing perforated product, the time to deploy could be greatly shortened.</p>
Saving	<p>The vast majority of solid bricks made in South Africa are produced with clamp kiln technology. Hence, cost saving calculations are focussed on a clamp yard nominally producing 30 million bricks per annum, in which perforations of 10% are introduced (three holes of about 33mm diameter). As it is commonly expected that the introduction of perforations at a clamp yard results in increased waste, an additional 3% loss due to waste is included in the calculations.</p> <p>Coal duff, the most common clamp kiln fuel source, is generally more expensive in coastal regions than inland. Assuming a fuel cost at the coast of R1,310/t and R800/t inland, annual cost savings are estimated as follows:</p> <p>Clamp Firing</p> <p>Assumptions: 30 million bricks produced per annum Perforations of 10% Raw material cost of R40/1000BE Cost to crush finer balanced by reduced volume required Initial firing energy requirement 11.0GJ/1000BE (based on solid bricks)</p>

Increase perforation size of extruded bricks	
Saving continued	<p>Firing fuel coal duff</p> <p>Inland cost: R800/t</p> <p>Coastal costs: R1,310/t</p> <p>Average delivery charges: R300/1000BE</p> <p>10% weight saving translates into a 5% saving on delivery costs</p> <p>Average brick sales price R1,300/1000BE</p> <p>Additional waste due to perforations: 3%</p> <p>Cost to move additional waste balanced by savings in moving lighter product elsewhere</p> <p>Energy saving assumed as proportional to perforation percentage</p> <p>Cost savings calculated from reduction in fuel cost, savings on raw materials and delivery charges, minus additional losses due to increased wastage</p> <p>Savings:</p> <p>Energy saving of 33,000GJ per annum</p> <p>CO₂ saving is 3,230t per annum (at 98kg CO₂ per GJ for coal).</p> <p>Coastal – R1.06 million per annum</p> <p>Inland – R415,000 per annum</p>
Payback	<p>Assuming the fuel costs used above, the balancing point of the payback calculation comes down to any additional waste produced. If the amount of additional waste can be kept at 3% or lower, payback is very quick and would justify the installation of additional clay preparation machinery if required. Based on the savings detailed above, simple payback is calculated as follows:</p> <p>Coastal – 2 weeks</p> <p>Inland – 1 month</p>
Site Energy/CO₂ saving per site	<p>Site energy saving: 33,000GJ per annum</p> <p>Site CO₂ saving: 3,230t CO₂ per annum</p>

Increase perforation size of extruded bricks	
Sector Energy/CO₂ saving potential	<p>Currently, 60% – 70% of brick manufacturing plants in South Africa use clamp technology and only a small percentage of those produce perforated bricks. The cumulative output of these plants varies significantly according to demand, but it can be reasonably assumed that a minimum of 1 billion solid bricks are produced annually in South African.</p> <p>20% shift to product with 10% perforations:</p> <p>Sector energy saving: 220,000 GJ per annum</p> <p>Sector CO₂ saving: 21,560 t CO₂ per annum</p> <p>100% shift to product with 10% perforations:</p> <p>Sector energy saving: 1,100,000GJ per annum</p> <p>Sector CO₂ saving: 107,800t CO₂ per annum</p>
Market penetration	<p>The South African brick industry has a history of resisting change and there is considerable resistance to the introduction of perforations. Although almost all extruded clay brick manufacturers could produce perforated bricks, the entrenched operational methodology of solid brick manufacturers will be difficult to change.</p> <p>Should a climate conducive to change be created by the correct blend of incentives and punitive measures, it is estimated that a 20% shift towards perforated products could occur over 10 years. After this time, if international trends are mirrored in South Africa, it is likely that output from brick producers who do not move forward and change will eventually be lost to alternative building products.</p>
Barriers to adoption	<ol style="list-style-type: none"> i. Entrenched operational methodology ii. Perception that “the market only wants solid bricks” iii. Lax environmental legislation iv. Technical difficulties v. Relatively low fuel costs in inland areas
Risks	<ol style="list-style-type: none"> i. Increasing environmental compliance / legislation requirements ii. Carbon tax iii. Clamp yards have long lead times and require significant investment in work in progress – this discourages trials iv. Labour volatility and willingness to pack solid bricks v. Market uptake of perforated bricks vi. Alternative building materials

6.3.6. Reduction of the Thermal Mass of Kiln Car Decks using Lightweight Refractory or Fibre

Reduction of the thermal mass of kiln car decks using lightweight refractory or fibre	
<i>Development</i>	
Description	<p>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.</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>Original solid refractory kiln car deck</p> </div> <div style="text-align: center;">  <p>Old inter-car seal</p> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;">  <p>New rope seal for inter-car sealing</p> </div> <div style="text-align: center;">  <p>Modern kiln car deck with large volume of lightweight insulation material</p> </div> </div>
	<p>Due to normal wear and tear, kiln car decks require renewal from time to time. In most cases, it is simpler for the plant operator to renew kiln car decks using the existing deck design. Nonetheless, in many cases, a redesign of the decks could lead to the incorporation of lighter weight materials, which would reduce thermal mass as well as conduction losses. 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.</p> <p>In addition, rebuilt kiln cars will also receive new inter-car seals. Over and above the fuel and cost saving from the lightweight decks, it is well-documented that inter-car seals of good quality can have a significant positive effect on tunnel kiln efficiency. Additional benefits in the form of decreased waste and improved yield are anticipated.</p>

Reduction of the thermal mass of kiln car decks using lightweight refractory or fibre	
Technology maturity and need for support	<p>South Africa currently has about 17 sites around the country employing tunnel kilns. Of these sites, about seven employ modern kiln car deck designs with support coming mostly from traditional European suppliers such as Burton and Forgestal, amongst others. Should a solution be needed, suppliers are willing and able to help, albeit at a cost.</p> <p>The remaining 10 tunnel kiln sites are generally either still maintaining their original kiln car detail, using homemade solutions or seeking alternatives such as those from Chinese suppliers. In this regard, local assistance is available from consultants and refractory suppliers. The CBA (or some of its members and associates), along with the EECB may provide some guidance to brick manufacturers wishing to upgrade their kiln cars.</p>
Possible project approach	<p>Many tunnel kiln operators lack the internal expertise to do anything else other than perpetuate their original deck design. In order to change to a lighter weight design, a consultant or engineering designer is needed to explore a range of options and ensure that a design is chosen that is fit for the particular duty in that particular plant – few tunnel kiln plants are exactly alike.</p> <p>While it would be ideal to build a few cars at a time and evaluate their performance, this is often difficult as old cars continually damage the newer cars. At a certain point, it becomes necessary to reconstruct large batches of cars that can generally run together, leaving only the first and last cars to get damaged by older cars.</p> <p>In a typical tunnel kiln plant, there may be 30 kiln cars in the tunnel kiln out of a total fleet of around 90 cars. Hence, even if 30 cars are refurbished, there will only be a short space of time when the kiln runs un-influenced by older cars. For this reason, it will be difficult to measure the overall kiln performance of the new cars with the refurbishment of a relatively small number of cars. In the short term, the performance of the design will most likely be evaluated on other aspects, such as its mechanical robustness.</p>
Estimated project cost	<p>Cost to deploy: R5.16 Million (at R57,000/car – lower end of the spectrum)</p> <p>Time to deploy: 2 – 3 years</p> <p>The cost is dependent on the size and state of the existing kiln cars. Should significant chassis repairs be required, the cost could be higher - and vice versa. Similarly, the time to deploy is based on a fleet of approximately 90 cars. If the plant can afford to refurbish three or four cars per month (from a cost as well as a process perspective), a complete refurbishment project could be completed within three years.</p>

Reduction of the thermal mass of kiln car decks using lightweight refractory or fibre	
Saving	<p>Due to the recovery of process heat that would otherwise be wasted, it is assumed that reducing the thermal mass of kiln car decks can achieve a 5% fuel saving. Other benefits, such as improved inter-car sealing and enhanced yields, have been assumed to provide an additional 5% gain in energy consumption.</p> <p>Assumptions: 30 million bricks produced per annum Initial firing energy requirement of 5.0GJ/1000BE Fuel cost: approximately R4/kg for fuel with 43MJ/kg energy content Energy saving calculated from reduced firing fuel consumption Cost saving calculated from reduction in fuel cost</p> <p>Savings: Energy saving: 15,000GJ per annum Cost saving: R1.4 Million per annum The CO₂ saving potential is 1,100 t per annum</p>
Payback	3.7 years
Site Energy/CO ₂ saving per site	<p>Site energy saving: 15,000GJ per annum Site CO₂ saving: 1,100t per annum</p>
Sector Energy/CO ₂ saving potential	<p>Of the 10 tunnel kiln sites that may benefit from reduced thermal mass kiln cars, 50% are unlikely to change their current operational thinking. Hence, replicability is limited to about five sites of varying outputs. Hence, the estimated saving per site is reduced to 10,000GJ per annum</p> <p>Sector energy saving:50,000GJ per annum Sector CO₂ saving:3,700t per annum</p>
Market penetration	<p>The five sites mentioned above are all likely to undertake kiln car refurbishment over the next five to 10 years. A climate of high business confidence conducive to change may speed up the process, but a two to three year project cycle per site ensures that this opportunity is long term. Hence, a 10-year estimate is suggested for the five sites mentioned above.</p> <p>Following initial uptake, new developments will create additional opportunities from time to time. Additionally, kiln car refurbishment is an ongoing item, but once lightweight deck design is embraced, the potential for energy reduction wanes significantly.</p>

Reduction of the thermal mass of kiln car decks using lightweight refractory or fibre	
Barriers to adoption	<ul style="list-style-type: none"> viii. Business confidence (concerns about consistency and volatility) ix. Cost and availability of finance x. Confidence in the mechanical robustness of old designs xi. Concerns over the mechanical robustness of light weight designs xii. Doubts over potential improvement
Risks	<ul style="list-style-type: none"> vii. Damage from old cars viii. Compatibility with existing cars ix. Mechanical robustness x. Cheaper refractory material from China may not match European quality xi. Labour volatility xii. Government legislation

6.3.7. Waste Heat Recovery

Waste Heat Recovery	
Description	<p>All kilns have exhausts through which 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.</p> <p>Kilns, tunnel kilns in particular, may also have other sources of waste heat that can be recovered. These include vented hot air from under car or roof cooling systems.</p> <p>There are two ways to recover the waste heat from exhausts:</p> <p>i) Use it directly as a source of heat</p> <p>This is possible when the contamination of the exhaust gases is low. This is a best practice with an excellent return on investment, as the implementation costs are low and all the heat can be recovered. Examples:</p> <ol style="list-style-type: none"> 1. Transfer of hot cooling air from the tunnel kiln cooling zone to the dryers; 2. The use of hot cooling air from the tunnel kiln cooling zone as preheated combustion air; 3. The use of hot cooling air from undercar cooling or roof cooling system as preheated combustion air. <p>The use of clean hot air from the kiln's cooling zone for drying is widespread for tunnel kilns and an increasing number of kilns are being built or modified so that lower temperature clean cooling air is used as preheated combustion air. Paybacks are almost always less than two years.</p>

Waste Heat Recovery



Tunnel kiln fired with preheated combustion air from cooling zone saving 50kJ/kg

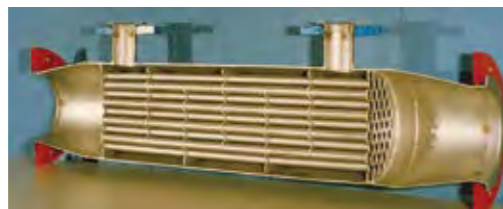
Courtesy of Lingl

ii) Use a heat exchanger to recover heat from exhausts

Heat exchangers are required when the exhaust gases cannot be used directly; almost all kiln exhausts fall into this category. Initial costs can be high for a heat exchanger but the resulting “free” heat stream can be used for a variety of purposes. Examples include:

1. Preheating combustion air;
2. Heating water;
3. Preheating heavy fuel oil prior to firing.

Unfortunately due to their longer payback of three to five years, there are few examples of flue gas heat exchangers in the brick industry. But as fuel savings from other sources become increasingly difficult to find, heat exchangers will become the major source of energy savings for the brick manufacturing business.



Shell and tube flue gas heat exchanger

Description continued

Technology Maturity

Heat exchanger design and technology is fully mature in sectors such as food, brewing and petro-chemical. Costs for the technology have decreased due to low steel prices and an increase in demand for mass produced products over bespoke designs. However, there is little expertise within the brick sector and its supply chain and the technology within the brick sector can therefore be considered to be at a very early stage in its maturity.

Project Approach

All kilns have the potential for heat recovery, but not all will be technically possible or economically sensible. The following simplified steps will guide companies in assessing their potential for heat recovery before investing in a full engineering study.

Waste Heat Recovery

Project Approach continued

1. Produce a heat balance for the kiln using a simple heat balance tool.
2. Identify the waste heat sources and whether the hot exhaust can be used directly or will need a heat exchanger.
3. If the hot air can be used **directly**, obtain quotations for ducting the hot air to the burners and for any adjustment to the combustion system to accommodate the increase in the temperature. Use the heat balance tool to calculate the saving by using this waste heat as preheated combustion air.
4. If a **heat exchanger** is required, the flue gas temperature should be above 150°C. Again, use the model to measure the value of the waste heat, but this time assume only part of it can be recovered using the formula:

$$\text{recovered heat value} = \text{value of waste heat} \times \frac{(T - 120)}{T}$$

where T is the temperature of the exhaust.

Obtain quotations for an installed heat exchanger and ductwork to the burner system and assess the business case thoroughly. The flue gases should be analysed for particulate and acid gas composition so that the correct grade of material can be used for the heat exchanger.

Estimated Project Cost

Vented Hot Clean Air:

Costs will be low with these types of projects, as they usually simply involve the connection of a waste heat source with the burner combustion air system; businesses can often complete the engineering work themselves. Ductwork should be made of a suitable material and be insulated. The burner combustion air control system will need to be adjusted to take into account a higher volume of higher temperature air. In some cases, with very hot combustion air, burner pipework may need replacing.

Project costs are variable depending on temperature, distances and burners deployed but a project cost of R200,000 to R1 million is typical. No or little extra maintenance cost is incurred. These projects can be implemented quickly with little interruption to the manufacturing process.

Heat Exchanger


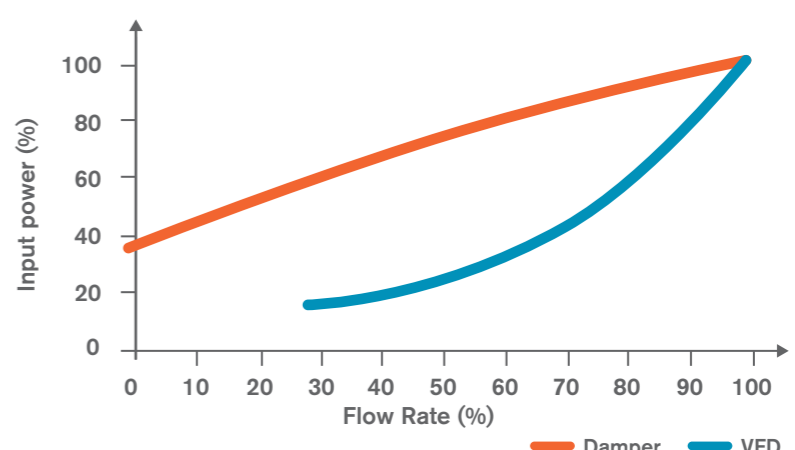
Project costs for heat exchangers are much higher. They require:

- Modifications to ductwork and burners or the oil delivery system;
- The purchase of a heat exchanger and the breaking into an exhaust stack.

Typical costs vary between R2 million and 10 million and there will be a small increase in maintenance costs from inspecting and cleaning the heat exchanger.

Waste Heat Recovery	
Estimated Project Cost	<p>The presence of a heat exchanger in the stack will increase the pressure in the system and a small increase in power consumption for the exhaust fan will occur.</p> <p>These projects take six months to one year to develop and require a shutdown to be installed.</p>
Saving & Payback	<p>Based upon an HFO kiln producing 30 million bricks per annum, with an energy consumption at 5GJ/000, 150,000GJ/year.</p> <p>Vented Hot Clean Air</p> <p>Assuming the kiln has a supply of 3,000 kg/hr of vented cooling air at 100°C, this represents 2,000GJ/year of heat that can be recovered as preheated combustion air.</p> <p>Saving: R0.2 million Estimated Project Cost: R500,000 Payback: 2.5 years</p> <p>Heat Exchanger</p> <p>Assuming the kiln has an exhaust temperature of 200°C, approximately 30,000GJ/year of heat is emitted through the stack, with a heat exchanger able to recover 12,000GJ/year.</p> <p>Saving: R1.1 million Estimated Project Cost: R5 million Payback: 5 years</p> <p>HFO with energy content 43MJ/kg HFO cost R4/kg</p>
Site CO₂ saving	<p>Based upon an HFO kiln producing 30 million bricks per annum, with an energy consumption at 5GJ/000, 150,000GJ/year.</p> <p>Vented Hot Clean Air: 140t CO₂/year Heat Exchanger: 870t CO₂/year</p>

6.3.8. Variable Speed/Frequency Drives

Variable Speed/Frequency Drives	
Description	<p>Variable Speed (or Frequency) Drives 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 also result in additional savings on fuel.</p>  <p>VSD and motor</p> <p>Where fans are used to control air flow or pressure within a kiln (such as the exhaust, combustion and cooling air), 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 variable speed drive 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%.</p>  <p>Power savings using a VSD (VFD) compared to damper control for reducing air flow.</p>
Technology Maturity	<p>Variable speed drives are a mature, but still developing technology. Their cost continues to drop, particularly for motor sizes below 500kW, they are now extremely reliable and last as long as the motor.</p> <p>VSDs are used as standard by kiln manufacturers for new tunnel kilns and are widely retro-fitted in tunnel and Hoffman kilns.</p>

Variable Speed/Frequency Drives

Project Approach

Identifying the opportunities to make savings with VFDs is relatively easy:

1. Identify all motors that control flow or pressure.
2. Does the motor have a damper that is used to control flow through the fan?
3. If the fan does not have a damper, would the process benefit from being able to control the flow?

If the answer to either of the last questions is yes, then a VSD will deliver process improvements and energy savings. As a rule of thumb, all exhaust fans deliver savings from a properly controlled VSD. Most combustion air and cooling fans will as well.

Variable speed drives can be expensive and require space in an air conditioned switch room or control cabin. Select the two or three motors that will deliver the highest rate of return rather than simply undertake a blanket installation programme.

Power savings can be estimated using the graph above or more accurately using the online saving calculators provided by technology providers. The business case will be most accurate when the performance curves of the fans are used along with the measured flows through them.

Fuel savings are usually delivered alongside power reduction and arise from reducing the amount of excess air forced into the kiln through combustion air and cooling fans, or removed through the exhaust fan.

Estimated Project Cost

The costs associated with variable speed drive projects are:

- The cost of VSD;
- The cost of housing the VSD (air conditioned control room required);
- The cost of a new fan (if required);
- The cost of installation (low if done in house).

They vary widely according to the size of the motor, the supplier used and the terms negotiated.

Some typical costs are:

motor, kW	VSD	motor
50	R100,000	R40,000
100	R200,000	R100,000
200	R400,000	R200,000

Installation costs are estimated at 25% of the equipment cost.

6.3.9. Energy Management

Energy Management

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 brick making, this means manufacturing saleable products with the lowest specific energy consumption (SEC) possible.

One of the reasons energy is often forgotten, even in an energy intensive process like brick making, is that it is often viewed as an uncontrollable fixed cost, rather than something we can actively control and reduce. Patterns of use and opportunities for savings are sometimes poorly understood.

For organisations that are used to managing resources such as labour, materials, output levels and quality, managing energy consumption is a simple transition - by incorporating it as a controllable variable cost into the production performance report.

The international standard ISO50001 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 and implementing improvements, and verifying the savings achieved as summarised in the diagram below.

Description

Within a company that has senior management commitment to energy management, the setting of reduction targets and providing weekly information on how well the process is performing is one of the most effective methods of delivering short term energy savings. Shires Bathroom reduced their energy bill by 11% within 12 months of implementing their own Energy Management System.

Energy Management

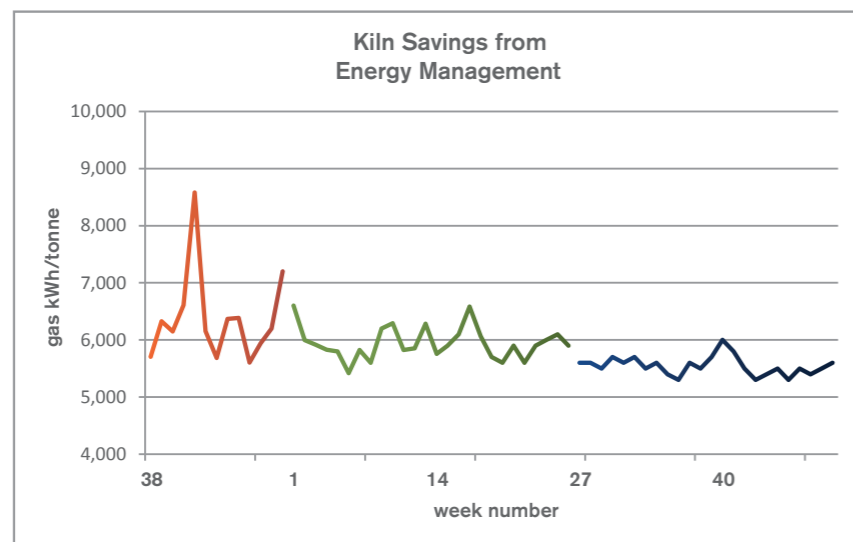
Shires Bathroom is a medium-sized sanitary ware company in the UK struggling to compete with the larger producers in the medium priced market sector. Having successfully increased production and quality to reduce overhead costs per item, they had seen their energy costs remain high, thus offsetting the savings they were achieving.

Shires formed an energy management team led by the production director with improved measurement and reporting at the heart. A weekly performance report was prepared on the energy consumption for each major process, i.e. casting, drying, firing and the boiler. The report was reviewed by the process managers and their teams each week so they could plan changes and measure the improvements, or otherwise, they delivered. By the end of the first year, they had reduced their energy consumption by 11%, saving £120,000 in their first year for a £10,000 investment.

Simple Reporting Tool Used

Apr-04		Target		7,776		
		13 week average		7,939		
		Saving/loss for quarter		-£1,172		
w/e date	production tonnes	gas actual kWh/tonne	gas target kWh/tonne	elec actual kWh/tonne	elec target kWh/tonne	variance £
04/04/2004	164	5,757	6,112	760	812	-740
11/04/2004	100	9,106	7,787	1,497	1,061	2,283
18/04/2004	0	0	0	0	0	0
25/04/2004	143	6,583	6,656	849	893	-252
TOTAL	408	6,871	6,715	972	902	1,290

Trend in Kiln Consumption, kWh/t



Case Study

6.3.10. Air Compressors

Air Compressors

Compressed air is an essential utility in many brickworks, but it is a very expensive one 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/kWh.

Compressors can be powered by electricity or by a diesel engine; 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, while reciprocating engines are capable of achieving higher pressures and are readily available with diesel power when power is not available at site or portability is important.



Screw compressor

Description



Reciprocating compressor

A single 100 kW (70hp) compressor operating 4,000 hours per year will typically consume R150,000/year. A large percentage of this energy is simple wasted in one or more of the following ways:

- i) System leakage through joints, holes, open valves (a 3mm diameter hole in a system at 7 bar will leak about 11 litres/sec and cost around 20,000 ZAR/year);
- ii) Storing compressed air at a higher pressure than is required;
- iii) Inefficient sequence management of multiple compressors;
- iv) Using warm intake air (it takes more energy to compress warm air);
- v) Compressors operating when there is no or little demand (compressors running on standby still consume 40% of the energy they need when operating at full load).

Air Compressors	
Technology Maturity	<p>High efficiency screw compressors have been on the market for many years. They are available with variable speed drives so that output is continually varied to match demand, thereby delivering more efficient operation when demand is below the design duty.</p> <p>Many manufacturers use more than one compressor to meet a variable demand patterns. Sequencing software is available that enables the most efficient compressor or combination compressors to be used to meet demand, and ensures those that are not needed are switched off.</p> <p>Integrated software is available on a modern compressor that allows the efficiency of their operation to be monitored on a daily basis and thus improvement action to be planned.</p>
Project Approach	<p>Optimising a compressed air system requires a simple systematic approach.</p> <ol style="list-style-type: none"> <p>1. Optimise the efficiency of supply</p> <p>Match the size of your compressor to your demand. If your demand is at a constant level and stable, a single fixed speed compressor with a standby compressor is ideal.</p> <p>If the demand is variable but predictable, a series of fixed speed compressor controlled by a sequence controller may be the best answer. If demand is un-predictable, a VSD compressor will be the most cost effective solution.</p> <p>Always ensure that the intake air is taken from the coldest source available, usually outside the building.</p> <p>Generate compressed air at the lowest pressure you need. For every one bar of pressure you drop, you will save 10%. If you have a small load at high pressure, consider a dedicated compressor.</p> <p>2. Improve distribution</p> <p>Design ring mains to be as short as possible and build in shut off valves for networks that are infrequently used.</p> <p>Do not oversize primary and secondary compressed air storage.</p> <p>Never keep condensate traps fixed open as they leak.</p> <p>3. Minimise Demand</p> <p>Operate a leak system check as part of routine maintenance and check for leaks at least once per month.</p> <p>Isolate redundant pipework.</p> <p>Avoid compressed air for cleaning and only use high efficiency nozzles.</p>

Air Compressors																			
Saving & Payback	<p>Example Saving (Electricity)</p> <p>Assuming a site has two 100kW compressors:</p> <ul style="list-style-type: none"> Each operating 4,000 hours/year; Each on standby (off load) 50% of the time; System pressure is 8 bar (maximum point of use pressure required 7 bar); Leakage levels are at 30% when measured by pressure decay at zero demand (quite normal for an unmaintained compressed air network). <p>The cost of running these two compressors is 560,000 kWh/year or R400,000/year.</p> <p>Savings (power only)</p> <table border="1"> <thead> <tr> <th>Best Practice Measure</th> <th>saving kWh/year</th> <th>saving ZAR/year</th> </tr> </thead> <tbody> <tr> <td>Controlling leaks to no more than 15% of demand</td> <td>84,000</td> <td>60,000</td> </tr> <tr> <td>Reducing supply pressure to 7.2</td> <td>38,000</td> <td>27,000</td> </tr> <tr> <td>Using a sequencer to reduce off load time from 50% to 10</td> <td>128,000</td> <td>92,000</td> </tr> <tr> <td>TOTAL</td> <td>250,000</td> <td>179,000</td> </tr> <tr> <td>Electricity cost R0.72 / kWh</td> <td></td> <td></td> </tr> </tbody> </table>	Best Practice Measure	saving kWh/year	saving ZAR/year	Controlling leaks to no more than 15% of demand	84,000	60,000	Reducing supply pressure to 7.2	38,000	27,000	Using a sequencer to reduce off load time from 50% to 10	128,000	92,000	TOTAL	250,000	179,000	Electricity cost R0.72 / kWh		
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Site CO₂ saving	<p>Two 100kW compressors after system optimisation</p> <p>270t CO₂/year (from electricity)</p> <p>Grid electricity 1.07 kg CO₂/kWh</p>																		

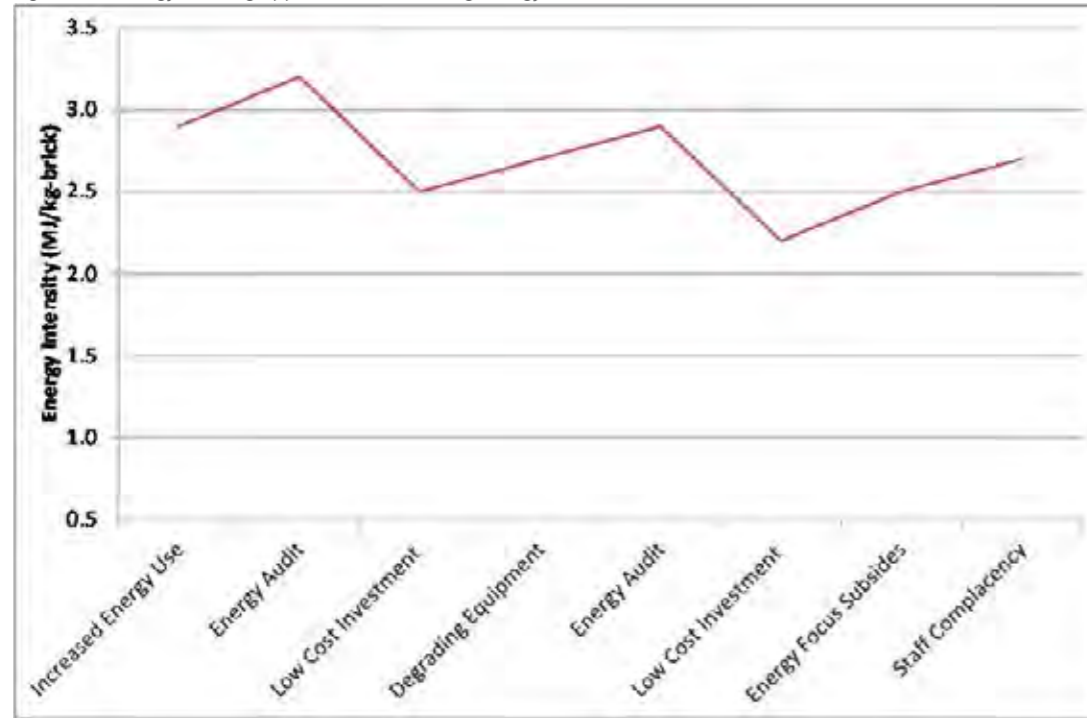
6.4. Energy Management Opportunities (and Reference to Existing Guides)

A number of guides for energy management have been developed and include the National Business Initiative document entitled "Energy Management: A Guide to Controlling Energy Use" (January 2014). Controlling the impact of rising energy costs and increased competition is crucial amongst the risk management objectives of any business. A

systematic approach is needed to ensure that businesses manage this risk and continually work towards improving energy performance. Two approaches exist with regards to efforts to control energy usage in a business, namely (i) the energy auditing approach; and (ii) the energy management approach.

These are outlined in the following figures.

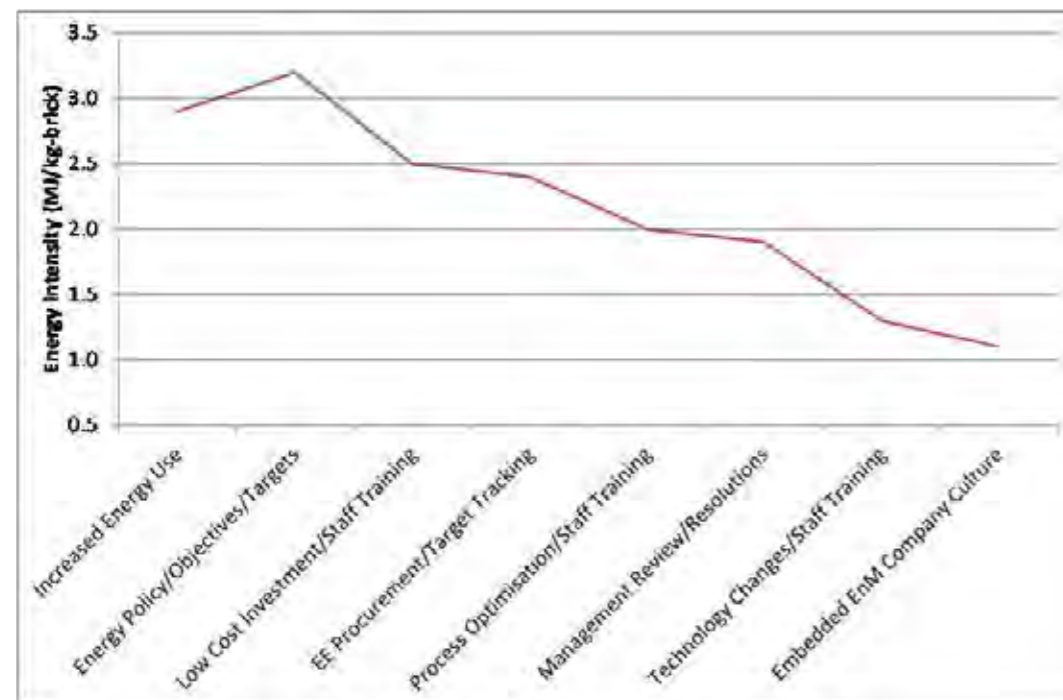
Figure 23: Energy auditing approach to controlling energy costs



The figure above indicates the haphazard approach to controlling energy costs through ad-hoc energy audits. Although the energy audit can provide focus on energy savings opportunities, the lack of a strategic plan to ensure long-term implementation of measures to reduce energy consumption results

in lost opportunities. A system approach would provide ongoing momentum in terms of reducing energy intensity, and is a holistic approach ensuring buy-in from the entire staff complement. This approach is indicated in the following figure.

Figure 24: Energy management approach to controlling energy costs



The Energy Management approach to controlling energy costs allows for the strategic development (driven by top management) of an energy policy which outlines objectives of the Energy Management System and operating targets (driven by management representative and Energy Management team). Through the incorporation of Energy Management in day-to-day operational activities, the awareness needed amongst all staff is facilitated. This ensures Energy Management is taken into procurement practices (ensuring energy efficient equipment is purchased and new designs take cognisance of energy performance) as well as ultimately creating an energy focus within the company culture, ensuring sustainability of the system and continuous improvement.

The following section describes the merits of a certified ISO50001 Energy Management System.

6.4.1. Relevance of ISO50 001

The Department of Energy has developed regulations entitled "Registration, reporting on energy management and submission of energy management plans". These regulations require companies whose total annual energy consumption exceeds 180TJ (50GWh) to apply to the Department within 90 days of the regulation promulgation date as per provided questionnaire under Annexure B of the regulation (other format) as relevant to Brickworks. This data is to be submitted via the Energy Efficiency Monitoring System (EEMS) web portal (www.eems.co.za), covering the following:

- Company details;
- Reporting period;
- Energy consumption, broken down into different energy carriers (including total energy use reported in TJ);
- Physical output in terms of production figures for various products relevant for the same reporting period for which energy data was provided;

- Economic gross output in terms of millions of rand.

The energy use data shall be submitted, for the preceding financial year, to the Department within 90 days of promulgation of the regulations, and thereafter the data shall be submitted within 60 days of the end of each financial year.

Companies with annual consumption equal to or exceeding 400TJ (111GWh) need to fulfil both the reporting requirements outlined above as well as develop an Energy Management Plan in accordance with the ISO50001. This plan is required within 12 months from the promulgation of the regulations (and renewed plans every five years thereafter) for which:

- Energy baselines need to be calculated in accordance with ISO50001;
- Energy efficiency savings potentials are identified;
- Energy performance indicators for monitoring energy performance are developed;
- Reporting on the implementation of the energy management plans, and achieved energy savings is carried out (required within 30 days of the end of each financial year).

Companies commencing operations, and whose total annual energy consumption is equal to or exceeds 180TJ after the promulgation of these regulations, must apply to be registered on the Energy Efficiency Monitoring System (EEMS) web portal (www.eems.co.za) within 30 days after commencement of such operations.

The following table provides an outline of the brickwork annual production for different product weights and differing kiln technologies (and hence energy intensities) for which either the (i) reporting requirements or (ii) reporting requirements and Energy Management Plan would be required.

Table 15: Production size of different brickworks triggering Energy Management Plans and/or reporting requirements

Brick Technology	Production of Bricks (2.6kg) per Year		Production of Bricks (3.2kg) per Year	
	Reporting Requirements	Energy Management Plan	Reporting Requirements	Energy Management Plan
Clamp Kiln (3.7MJ/kg-brick)	19-42 Million	≥ 42 Million	15-34 Million	≥ 34 Million
Clamp Kiln (3.0MJ/kg-brick)	23-51 Million	≥ 51 Million	19-42 Million	≥ 42 Million
Clamp Kiln (2.4MJ/kg-brick)	29-64 Million	≥ 64 Million	23-52 Million	≥ 52 Million
Tunnel Kiln (2.1MJ/kg-brick)	33-73 Million	≥ 73 Million	27-60 Million	≥ 60 Million
Hoffman Kiln (1.5MJ/kg-brick)	46-103 Million	≥ 103 Million	38-83 Million	≥ 83 Million
VSBK (1MJ/kg-brick)	69-154 Million	≥ 154 Million	56-125 Million	≥ 125 Million

The table outlines that only the smaller brickworks will be exempt from both energy reporting requirements, while only the large brickworks will be required to fulfil both the reporting requirements and Energy Management Plan. The lower the energy intensity of the brickworks, the greater the production of bricks allowed before the requirement of either fulfilment of the Energy Management Plan and/or reporting requirement.

It is important to note that if the site / company already has an ISO14001, ISO9001, or ISO22001 system in place, the Energy Management System can be built off these platforms with the extension of the systems to include the energy relevant aspects as well as the following additional items not covered in the clauses of the aforementioned standards:

- Management Responsibility (if related to ISO14001 standard);
- Development of an Energy Baseline;
- Development of Energy Performance Indicators;
- Documentation Requirements (if related to ISO14001 standard);
- Design of Facility Energy Efficiency Requirements (if related to ISO14001 standard);
- Procurement of Energy Efficiency Services, Products, Equipment and Energy (if related to ISO14001 standard).

The basic roles and responsibilities of management and management representative as defined in the SANS ISO 50 001 standard are highlighted in the alongside table.

Table 16: SANS ISO 50 001 management system roles and responsibilities

Topic	TOP MANAGEMENT	MANAGEMENT REPRESENTATIVE
1. Energy Policy	Defining, establishing, implementing, and maintaining an energy policy	Ensure planning of EnM activities are designed to support the energy policy
	Conducting Management Reviews	Promote awareness of energy policy and strategic energy objectives on all levels
2. EnMS Framework	Identifying scope and boundaries to be addressed by EnMS	To ensure compliance with the international standard and is continuously improved
	Providing necessary resources to establish, implement, maintain and improve the EnMS and resulting energy performance	Identify individuals to support the EnM activities
3. Resources	Appointment of a management representative and consent to the formation of an Energy Management team	Define and communicate responsibilities and authorities in order to facilitate effective EnM
	Communicate the importance of EnM within the organisation	To report to top management with respect to energy performance and the EnMS performance
5. Project Management and Monitoring	Ensuring that energy objectives and targets are set	Determine criteria and methods necessary to ensure both operation and control of EnMS are effective
	Ensuring that EnPIs are appropriate for organisation	
	Considering energy performance in long-term planning	
	Ensuring results are measured and reported at determined levels	

For small brickworks not requiring an Energy Management Plan but still wanting to benefit from such a system, a more simplified version as detailed below could be applied.

Table 17: Procedure for development of simplified Energy Management System for small brickworks

Simplified EnM System	Format
ENERGY POLICY: Written or electronic declaration of commitment of the management to introduce an alternative system and operate	Signed undertaking
RESOURCES: Energy Management Representative appointed for monitoring and maintenance of energy data collection and assessment	Written appointment of an Energy Management Representative (may be portion of existing job) with roles and responsibilities
TRACKING ENERGY CONSUMPTION: Traceable documentation of current energy sources and energy use amounts for minimum the last 12 months and, where possible, in recent years <ul style="list-style-type: none"> In physical units (kWh) and the cost (rand) Percentage of individuals energy users Data source (measuring system, precision) 	Spreadsheet/tracking system
SCOPE AND BOUNDARIES: Detailed corporate statement on applied energy sources, locations	Top management declaration that all energy sources and locations were fully covered
AREAS OF SIGNIFICANT ENERGY USE: <ul style="list-style-type: none"> Analysis of energy consumers Directory/table of installations, equipment, plant components, consumption groups, consumption areas (capacity, performance, year of construction, energy demand) Information on temperature level and amount of usable waste heat Documentation of measuring methods and devices 	<ul style="list-style-type: none"> Description of assessment methods and information on measuring devices Maintenance Manual, measurement protocols
ENERGY SAVINGS OPPORTUNITY LIST/TARGETS: Determination of potential savings based on the energy review and development of Energy Performance Indicators (EnPIs) e.g.: kWh/kg-brick	List of possible targets (linked to EnPIs, etc.), minutes of meetings
FINANCIAL EVALUATION OF OPPORTUNITIES: Economic evaluation of measures for the use of potential savings calculations	Internal rate of return/net present value/payback period company protocols
IMPLEMENTATION PROGRAMME: Documented energy savings program	Action plan with responsibilities, deadlines and resources
MANAGEMENT REVIEW (CHECKING): Evidence that the management was informed of the results of simplified EnM system	Minutes, signed documentation
RESOLUTIONS FOR SYSTEM/EnPI IMPROVEMENT: Decisions on measures of meetings	Signed action plans

6.5. Industrial Symbiosis

Definition: Industrial symbiosis is the sharing of services, utility, and by-product resources among industries in order to add value, reduce costs and improve the environment. Industrial symbiosis is a subset of industrial ecology, with a particular focus on material and energy exchange.

Our current industrial processing and production are on an unsustainable path of growth and development. One tool to address sustainability in industrial activities is industrial symbiosis. This is a resource efficient approach where unused or residual resources of one company are used by another company. Resources could include material, energy, water, assets, logistics, knowledge, etc. and this typically results in mutual economic and environmental benefits.

Some of the benefits that flow from these symbiotic relationships are:

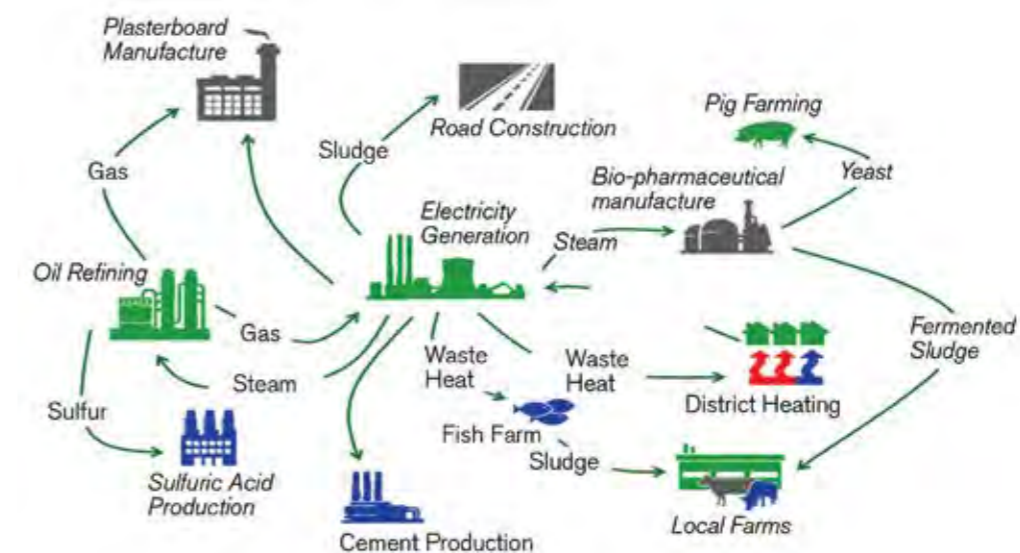
- A greater diversion of waste disposal to landfill sites;
- Reduced raw material input costs to recipient companies;
- Reduced transport footprint for companies transporting waste to distant landfill sites;
- Reduced energy consumption required for the conversion of virgin material; and

- Reduced CO² emission resulting from lower waste volumes at landfill sites.

Industrial symbiosis uses various tools to engage with companies. These include business opportunity workshops, individual company meetings and company site visits, which help to ascertain how industrial symbiosis can be beneficial to participating companies.

In a typical business opportunity / synergy identification workshop, companies present all the un-utilised resources they generate, inviting discussions with those companies interested in using their waste resources and by-products as an input in their business processes; synergies will be created in this manner. An industrial symbiosis facilitator will capture all the potential synergies into a management system to follow-up and drive action. Individual company reports with potential identified synergies will be generated and sent to each individual company for further follow ups. The facilitator assists companies seeking to identify additional synergies and provides support in the implementation of these synergies, facilitates negotiations with companies and provides technical support.

Figure 25: Schematic of a typical industrial symbiosis network



Early industrial waste symbiosis programmes failed to generate sufficient interest to sustain the synergies and symbiotic business relationships which are key drivers of successful IS programmes. Central to these failures was the difficulty of identifying waste opportunities.

Through the use of industrial symbiosis methodology, it is anticipated that brick manufacturing facilities are most likely to gain substantial economic benefit from the use of other industries waste materials like slag and waste sand. The case studies that have so far been generated as explained below indicate how this has been feasible (Case Study based on UK Scenario).

MJ Allen provides ferrous and nonferrous castings in the UK and abroad. As with many cast metal producers, MJ Allen were incurring significant disposal costs for spent foundry sand from the metal casting process. While sand was recycled on site as far as possible, it eventually loses the properties required for moulds.

MJ Allen's site in Kent contacted Industrial Symbiosis in the UK to look for alternative solutions for nearly 500 tonnes of sand being sent to landfill every year. After suggesting several industrial members that could use the sand, it transpired that one, Hanson Aggregates, were supplying virgin sand to the foundry. Hanson is one of the UK's largest suppliers of construction materials, and often use recycled materials. Discussions and investigation began on the take-back solution for the site.

It was also found that the waste sand is often suitable for use in asphalt, cement, bricks and pipe bedding. After discussion and investigations between MJ Allen and Hanson, it became clear that by collecting the sand for use as a recycled aggregate, Hanson could make good use of a resource otherwise destined for landfill. Meanwhile, the arrangement would save MJ Allen over £30,000 a year and help them improve their environmental performance.

In order to enable sand collections, new pipework was required and the foundry was happy to invest the time and money in this infrastructure. Regular collections are now being made by Hanson who stockpile the material and process it for use in asphalt products.

The results that were generated from this intervention were calculated in terms of CO² reduction (49 tonnes/year) and cost savings (£36,546.00/year).

- Landfill diverted: 480 tonnes/year
- Private investment: £3,000
- Virgin materials: 498 tonnes/year
- Water: 18 tonnes equivalent/year

While there are many examples of foundry sand reuse in construction materials, the potential has not yet been fully realised in foundries across the South African market. NCPC-SA - with the current industrial symbiosis programme in its infancy stage - is keen to spread the word among its stakeholders.

6.6. Training

It is estimated that there are 300,000 brick kilns throughout the world man

6.6.1. Green Skills Development Initiatives of the NCPC-SA

One of the NCPC-SA's key strategies involves the development of "green skill-sets" that would facilitate more resource efficient and cleaner production (RECP) practices. It is in pursuit of this objective that the NCPC-SA aims to commission the development of a number of training packages, designed to equip RECP Practitioners/Professionals with specialist skill-sets.

As the implementation partner of UNIDO's IEE Project, the NCPC-SA's recent focus was on training courses related to energy efficiency, developed by UNIDO-contracted international experts. The NCPC-SA also initiated the development of new

RECP training courses. The list of training offerings include a two-day classroom-based theoretical workshop, followed by expert training that combines theory and workplace training over six to nine months in each of the following disciplines:

- Energy Management System Implementation
- Industrial Energy System Optimisation
 - o Steam System Optimisation
 - o Compressed Air System Optimisation
 - o Fan System Optimisation
 - o Pump System Optimisation
 - o Process Heating System optimisation
 - o Motor System Optimisation
- Resource Efficiency and Cleaner Production

The objectives and learning outcomes of the respective offerings are as follows:

Energy Management System –two-day End-user Training Programme

Objective: The objective of this two-day training, targeted at enterprises' staff responsible for developing and implementing the Energy Management System within the company, is to provide trainees with the knowledge, understanding and tools that will enable them to initiate the development and implementation of an EnMS aligned with ISO 50001.

Learning goals: By the end of the two-day user training, the trainees will have achieved the following learning goals:

1. Good understanding of the elements of an EnMS;
2. Good understanding the benefits of EnMS and ISO50 001;
3. Ability to put together a high-level project management plan (time, resources, costs, etc.) to implement an EnMS within their organisation;

4. Understanding of the assistance and services offered by the UNIDO Project and where to find additional resources and information;
5. Ability to report back to top management on the EnMS and its benefits;
6. Ability to initiate the development and implementation of an EnMS.

Energy Management System Implementation - Expert Training Programme

Objective: The objective of the EnMS Expert Training Programme is to create a cadre of national experts equipped with the knowledge, skills and tools needed to support adoption and implementation in the industry of aligned Energy Management Systems, which conform to ISO50 001. This is done by providing technical assistance to enterprises and coaching of facility personnel on EnMS development and implementation. The trained national experts will then be able to:

1. Promote and sell EnMS and ISO500001 to industry management;
2. Work with enterprise to establish and implement EnMS that functions, i.e. deliver energy performance improvements;
3. Work with enterprise to establish and implement EnMS that fully conform with ISO50 001;
4. Build EnMS development and implementation capacity of enterprises' personnel;
5. Conduct ½ day workshop for factory manager sand management, raising awareness of the benefits and costs of implementing an EnMS in conformance with ISO50 001 and presenting the range of technical and financial assistance to be made available by UNIDO Projects;
6. Conduct two-day user training for enterprise Energy Managers and other relevant personnel on how to develop and implement an EnMS aligned with ISO50 001.

Learning goals: At the end of the Expert Training Programme, national trainee/experts shall have gained the following knowledge, expertise and skills:

1. Immediate and strategic benefits of EnMS/ISO50 001 implementation;
2. National legislation and regulation relevant to the adoption and/or implementation of EnMS and/or ISO50 001;
3. Financing options available for Energy Efficiency Projects and EnMS/ISO50 001 implementation;
4. Working understanding of all elements of an Energy Management System in conformance with ISO50 001;
5. Working understanding of resource requirements and costs involved in the implementation of EnMS/ ISO50 001 in industry;
6. Ability to apply an EnMS in an industrial facility;
7. Experience in the practical implementation of an EnMS, including use of supporting tools;
8. Ability to and experience in reviewing an EnMS, verifying and reporting on energy performance;
9. Ability and experience to effectively deliver ½ day awareness workshop and 2-day training on energy management system and ISO50 001.

Steam System Optimisation – End-user Programme

Objective: The objective for the three days of steam end-user training is to provide more in-depth technical information on undertaking an industrial steam system energy assessment and making improvements to industrial steam systems. Additionally, it aims to provide hands-on training for using all the US DOE steam system Best Practices software tools in the field while doing an industrial steam system energy assessment.

Learning goals: At the completion of the three-day end-user training on SSO, participants will be able to:

1. Use the ASME Steam System Energy Assessment Standard (ASME-EA-3-2009) and undertake field work to do the steam system assessments;
2. Identify gaps and deficiencies in energy efficiency in industrial steam systems;
3. Ask for specific field data and measurements required to undertake a steam system assessment;
4. Develop a model simple steam system project using fundamental law of physics, thermodynamics and heat transfer;
5. Proficiently use the US DOE Steam Best Practices software tools (SSST, SSAT and 3EPlus) and/or other resources to evaluate the steam systems, identify optimisation opportunities in industrial plants and conduct an impact – level analysis;
6. Create a preliminary report that summarises the findings from the steam energy assessment.

Steam System Optimisation – End-user Programme

Objective: The primary objective of the SSO Experts Training Programme is to create a cadre of national experts equipped with the knowledge, skills and tools needed to support adoption and implementation of steam system optimisation in industry. The national SSO Experts will provide technical assistance to enterprises and coach facility personnel on SSO development and implementation. The trained national experts will work with enterprises to establish and implement SSO that functions, i.e. delivers energy performance improvements and sustainable best practices.

Learning goals: A further goal of the Expert Training Programme is to select a smaller group of national experts (at least four per country) who will also be equipped with skills required to promote and “sell” SSO to industry and build basic SSO development and implementation capacity of enterprise personnel. These selected national experts will also:

1. Conduct one-day Basic SSO training on steam systems assessment, identification of optimisation measures and implementation of operational improvements;
2. Conduct two-day Advanced SSO training on steam systems assessment, identification, development and implementation of optimisation measures and projects.

At the completion of the Experts Training on SSO, in addition to the learning goals mentioned in the one-day Basic and two-day Advanced training sections above, participants shall have gained the knowledge, expertise and skills in the following areas:

1. Immediate and strategic benefits of undertaking industrial steam system assessments;
2. Ability to apply a SSO methodology in an industrial facility;
3. Working understanding of all elements of an industrial SSO methodology, including planning, implementation, performance checking and review;
4. Working understanding of resource requirements and cost involved in the SSO implementation in industry;
5. Experience in practical implementation of SSO including use of Best Practices tools and resources;
6. Working and hands-on knowledge of field data, measurement and verification of potential benefits, projects complexities, technological barriers and operational risks that may exist in industry;
7. Benefits of doing detailed due-diligence on projects to be implemented from the results of the industrial steam systems assessments;
8. Working with a vendor and/or service provider (such as an engineering company) to design, specify and procure state-of-the-art equipment that may be required for the SSO project implementation;

9. Create a case-study level report that summarises the success of the SSO Project and which can be disseminated industry-wide as a testimonial or success story of replication in similar or other applications;
10. Ability to and experience in reviewing an existing SSO system, verifying and reporting on its energy performance;
11. Ability to and experience in effectively delivering a one-day Basic and two-day Advanced (in tandem with another national/international expert) training in SSO (will apply to only few trainees selected to become national SSO trainers).

Pump System Optimisation – Two-day End-user Programme

Objective: This two-day PSO end-user training is primarily designed to build enterprise personnel's comprehension of and technical capacity for PSO and to enable them to initiate the development and implementation of PSO measures and projects. The training is also intended to raise further enterprises' interest in the UNIDO technical assistance offer for complex PSO project implementation.

Learning goals: The participants (facility engineers, operators and maintenance staff of enterprises, as well as energy service providers) will recognise the benefits of PSO, learn how to assess their pump systems, identify potential optimisation opportunities, and determine how to achieve cost savings and energy efficiency through appropriate application of pumps in new and existing systems, different control methods and maintenance and operational best practices. They will also learn how to make cost calculations and quantitatively assess pump systems and potential improvement opportunities, also through the use of software tools such as the Pump System Assessment Tool (PSAT).

Learning Objectives:

1. Define PSO and LCC;
2. Understand the importance of pump systems

optimisation and the importance of a Life cycle cost analysis;

3. Perform a group exercise on conducting a PSO and consider how to pre-screen pump systems;
4. Recognise types of pump systems and understand the importance of the systems approach;
5. Understand pump system fluid relationships and performance curves;
6. Pump equation, affinity laws and pump system calculations;
7. Recognise the importance of field measurements and perform a group exercise on using field measurements;
8. Recognise the benefits of the PSAT software tool and how it can be used to identify potential opportunities;
9. Be aware of pump system optimisation resources and review the next steps they should take if they are interested in PSO;
10. Understand how to select pump system optimisation providers and report their take-away from the training;
11. Understand the PSAT software tool through a practice example;
12. Outline how to apply best practices to correct operational and maintenance deficiencies;
13. Correctly apply variable frequency drives and have basic understanding of the international Pump Assessment Standard;
14. Identify a template to build a business case to justify additional resources to implement optimisation projects, create an action plan for PSO and report their key take-away from the training.

Pump System Optimisation - Expert Training Programme

Objective: The objective of the PSO Expert Training

Programme is to create a cadre of national experts equipped with the knowledge, skills and tools needed to support implementation of PSO in industry by providing the following services:

1. Technically assisting enterprises and coaching facility personnel on pump system optimisation project development and implementation; and
2. Conducting the PSO end-user training on pump system assessment, identification of optimisation measures, and development and implementation of operational improvements.

Learning goals: At the end of the PSO Expert Training Programme, national trainees / experts shall have gained the following knowledge, expertise and skills:

1. In depth understanding of the benefits of pump system optimisation.
2. Ability to pre-screen pump systems and identify potential energy saving opportunities;
3. In-depth understanding of pump and system curves and pump optimisation calculations;
4. Ability to conduct pump system assessments in accordance with international pump system assessment standards;
5. Ability to use flow, pressure and power measurement instrumentation to collect field data;
6. Having practical experience in using the PSAT software tool;
7. Ability to determine the most cost effective pump system improvements and correctly applying variable frequency drives;
8. Effectively delivering the two-day end-user training. This goal will apply only to trainees.

Electric Motors Optimisation – Two-day End-user Programme

Objective: This two-day MSO end-user training is primarily designed to build or consolidate

enterprise personnel's understanding of MSO and technical capacity for MSO oriented actions and to enable them to initiate the development and implementation of MSO measures and projects. The training is also intended to raise further interest in the UNIDO training and technical assistance offers.

Learning goals: The participants will recognise the benefits of MSO and learn how to qualitatively assess motor systems and identify potential optimisation opportunities, and determine how to achieve cost savings and energy efficiency through appropriate application of motor in new and existing systems, different control methods and maintenance and operational best practices. The participant will learn how to effectively present MSO benefits and opportunities to management.

Learning objectives: During the training, the participants will:

1. Define motor and motor system;
2. Differentiate between motor types;
3. Define motor energy performance and efficiency, and understand the factors that influence it;
4. Learn about standards relating to motor system energy efficiency;
5. Recognise the benefits of MSO;
6. Assess different control methods;
7. Discuss how to conduct MSO;
8. Prioritise enterprise-wide MSO opportunities;
9. Calculate the cost-savings of MSO.

Electric Motors Optimisation - Expert Training Programme

Objective: The MSO Expert Training Programme is an intensive training delivered by leading international Motor Systems Optimisation (MSO)

experts to national energy efficiency experts, service providers, equipment vendors and industry engineers. This training provides more in-depth technical information on troubleshooting and making improvements to industrial motor systems. This training also introduces basic principles for energy efficient design of motor systems, how to successfully sell motor systems improvement projects to management and how to select a motor system optimisation service provider. National experts are trained through classroom, on-the-job and coaching by international MSO experts and equipped with the expertise, skills and the tools required for providing the following services:

1. Technical assistance to enterprises and coaching facility personnel on motor systems optimisation projects development and implementation;
2. Conducting two-day MSO training on motor systems assessment, identification of optimisation measures, development and implementation of operational improvements.

Learning goals: The participants (national energy efficiency experts, service providers, equipment vendors and industry engineers) will learn how to assess motor systems and saving opportunities, evaluate and prioritise optimisation strategies, gain understanding of maintenance issues and how they relate to energy saving, carry out a full MSO assessment, and work with the partner enterprises to prepare and implement MSO measures and investment projects so that they can qualify as UNIDO MSO Experts and their customers can achieve energy efficiency and cost savings.

Learning objectives: During the training, the participants will:

1. Review key concepts relating to motor systems applications, optimisation and auditing;
2. Examine advanced motor technologies;
3. Review factors affecting motor system efficiency;
4. Evaluate different control strategies;

5. Assess power quality and other reliability issues (voltage levels, voltage unbalance, harmonics, voltage sags, micro-interruptions and ride through capabilities);
6. Select appropriate measurement strategies;
7. Screen for motor-based opportunities in fluid power systems;
8. Systematically screen for the most promising motor systems for energy savings;
9. Interpret claims for voltage optimisation products;
10. Quantify and rank optimisation strategies;
11. Report their key take-away from the session;
12. Screen for opportunities;
13. Decide what measurements to take;
14. Take measurements;
15. Analyse results.

Fans system Optimisation – Two-day End-user Programme

Objective: This two-day FSO end-user training is primarily designed to build enterprise personnel's comprehension of and technical capacity for FSO and enable them to initiate the development and implementation of FSO measures and projects. The training is also intended to raise further interest in the UNIDO technical assistance offer for complex FSO project implementation.

Learning goals: The participants (facility engineers, operators and maintenance staff of enterprises, as well as energy service providers) will recognise the benefits of FSO and learn how to qualitatively assess their fan systems and identify potential optimisation opportunities, determine how to achieve cost savings and energy efficiency through appropriate application of fans in new and existing systems, different control methods and

maintenance and operational best practices. They will also learn how to make cost calculations and quantitatively assess fan systems and potential improvement opportunities, also through the use of software tools such as the Fan System Assessment Tool FSAT.

Learning objectives: During the training, the participants will:

1. Discuss key terms and concepts of FSO;
2. Examine different fan types and control components;
3. Explain the benefits of FSO;
4. Assess how well each fan system is meeting the specific enterprise process needs;
5. Calculate the cost of operating fans;
6. Prioritise enterprise-wide system optimisation opportunities;
7. Assess how well each fan system is meeting the specific enterprise process needs for heating/cooling/drying;
8. Calculate the cost of operating fans;
9. Outline how to apply best practices to correct operational and maintenance deficiencies;
10. Explain the purpose and functions of the FSAT software;
11. Describe how to use FSAT software for fan system inputs;
12. Describe how to use FSAT software for fan system outputs;
13. Practice using FSAT software to complete FSAT optimisation ratings;
14. Identify a template to build a business case to justify additional resources to implement optimisation projects;
15. Create an action plan for FSO;
16. Report their key take-away from the training.

Fan System Optimisation - Expert Training Programme

Objective: The objective of the FSO Expert Training Programme is to create a cadre of national experts equipped with the knowledge, skills and tools needed to support adoption and implementation of FSO in industry, by providing the following services:

1. Technically assisting enterprises and coaching facility personnel on Fan System Optimisation Project development and implementation; and
2. Conducting the two-day FSO end-user training on fan system assessment, identification of optimisation measures, and development and implementation of operational improvements.

Learning objectives: During the training, the participants will:

1. Review key concepts related to qualitative and quantitative assessments of fan systems, explain terms, concepts and equipment involved with measuring fan system performance;
2. Discuss ISO measurement standards;
3. Develop a measurement plan based on ISO standards;
4. Take on-site fan system measurements according to ISO standards, calculate fan flow rate and other performance parameters based on the field data according to ISO standards, use the performance test results, assess FSO potential; and report their key take-away from the session;
5. Develop a list of relevant FSO strategies, review affinity laws and control strategies and quantify and rank optimisation strategies;
6. Discuss how to report findings and recommendations to customers and analyse how to avoid and troubleshoot fan system problems;
7. Review duct system design parameters;
8. Apply FSAT to analyse a FSO opportunity and report their key take-away from the session;
9. Report their FSAT findings;

10. Describe heat recovery opportunities and strategies;
11. Discuss motor and variable speed drive selection criteria and application tips;
12. Discuss relevant parameters for fan systems that transport materials;
13. Review key design parameters for industrial ventilation systems;
14. Design a new energy efficient fan system;
15. Explain how to prepare FSO projects for management investment decisions and for financing and report their key take-away from the session.
16. Take the final written and oral exam to qualify as a UNIDO FSO Expert.

Compressed Air System Optimisation – Two-day End-user Programme

Objective: This two-day CASO End User training is primarily designed to build enterprise personnel's comprehension of and technical capacity for CASO and to enable them to initiate the development and implementation of CASO measures and projects. The workshop is also intended to raise further enterprises' interest in the UNIDO technical assistance offer for complex CASO project implementation.

Learning goals: The participants (facility engineers, operators and maintenance staff of enterprises, as well as energy service providers) will recognise the benefits of CASO and learn how to qualitatively assess their compressed air systems and identify potential optimisation opportunities, and determine how to achieve cost savings and energy efficiency through appropriate application of compressed air in new and existing systems, different control methods and maintenance and operational best practices. They will also learn quantitatively assess compressed air systems and potential improvement opportunities.

Learning objectives: During the training, the participants will:

1. Discuss key terms and concepts of compressed air systems;
2. Explain the types of compressors;
3. Examine different component types and the system design;
4. Explain the importance of condensation in the compressed air system;
5. Assess how well each system component is meeting the specific enterprise quality requirements;
6. Calculate the cost of operating the compressed air system;
7. Prioritise enterprise-wide system optimisation opportunities;
8. Identify system design factors
9. Identify caso opportunities and evaluate an existing system;
10. Design a demand profile;
11. Calculate the cost of operating a compressed air system;
12. Outline how to apply best practices to correct operational and maintenance deficiencies;
13. Report their key take-away from the workshop.

Compressed Air system optimisation -Expert Training Programme

Objective: The objective of the CASO Expert Training Programme is to create a cadre of national experts, equipped with the knowledge, skills and tools needed to support adoption and implementation of CASO in industry by providing the following services:

1. Technically assisting enterprises and coaching facility personnel on compressed air system optimisation project development and implementation; and
2. Conducting the two-day CASO end-user workshop on compressed air system assessment,

identification of optimisation measures, and development and implementation of operational improvements.

Learning goals: The participants (national energy efficiency experts, service providers, equipment vendors and industry engineers) will learn how to measure compressed air systems and assess CASO opportunities, evaluate and prioritise optimisation strategies, troubleshoot compressed air system problems, design energy efficient compressed air systems, carry out a full CASO assessment, and work with the partner enterprises to prepare CASO investment projects so that they can qualify as UNIDO CASO Experts and their customers can achieve energy efficiency and cost savings.

The participants will become comfortable with the training philosophy and adult learning principles that form the basis for the CASO end-user training format and methodology so that they can effectively facilitate the training in the future. They will also learn how to effectively coach different personality types in CASO projects.

Learning objectives: The Standards of Knowledge is a list of the prerequisite knowledge that is needed to pass the UNIDO Compressed Air System Expert certification exam.

1. Definitions and gas laws associated with compressed air systems;
2. Understand compressors and components of the compressed air system;
3. General operating principles and types of positive displacement and dynamic compressors;
4. Understanding pressure drops;
5. Understanding Air Treatment;
6. Determine proper storage requirements;
7. Identify the sources of demand and evaluate their appropriateness;
8. Quantify the impact of variations in the compressed air supply on plant production;

9. Establish a baseline of system performance;
10. Develop a pressure profile;
11. Identify the sources of demand, including; 1) system applications, 2) critical flow applications, and 3) leak load;
12. Calculate energy costs associated with various components of the system;
13. Calculate lifecycle costs of components;
14. Compressed air quality requirements;
15. Estimate the cost impact of poor air quality on production;
16. Take measurements to document the dynamics of the system;
17. Recommend changes that will improve system performance and reduce operating costs.

5. Understand how to identify and prioritise detailed assessment focus areas;
6. Know which user-friendly RECP software is available;
7. Know which RECP metrics are important;
8. Be eligible to attend the Advanced RECP Course.

Resource Efficiency and Cleaner Production Expert Training

Objective: This is a practical course with significant amounts of practical or fieldwork involved. On successful completion of this course, participants will:

1. Have reviewed the pertinent contents of the RECP Basic Course;
2. Have completed a variety of case study discussions illustrating the various aspects of the RECP process;
3. Have undertaken an assisted RECP pre-assessment;
4. Have undertaken a comprehensive RECP assessment of their host plant and made suitable recommendations;
 - a. Have prepared for undertaking an RECP Assessment;
 - b. Have collected data for RECP analysis
 - c. Have reviewed the data captured and determined trends and problem;
 - d. Have generated RECP solution options;
 - e. Undertaking feasibility assessment for RECP interventions;
 - f. Have implemented RECP interventions;
 - g. Institutionalise RECP interventions through controlling and improvement;
5. Be able to undertake a pre-assessment;
6. Be able to use user-friendly RECP software and RECP metrics.

RECP Two-day End-user Training

Objective: This is a theoretical course with no practical or fieldwork involved. Upon successful completion of this course, participants will:

1. Understand why RECP is an important initiative;
2. Understand the evolution of the RECP Programme;
3. Understand the major steps in conducting a RECP Assessment;
 - a. Preparation for undertaking an RECP Assessment;
 - b. Collecting Data for RECP analysis;
 - c. Reviewing the data captured and determining trends and problems;
 - d. Generating RECP solution options;
 - e. Undertaking feasibility assessment for RECP interventions;
 - f. Implementing RECP interventions;
 - g. Institutionalising RECP interventions through controlling and improvement;
4. Understand the content and process of a pre assessment;

7. Next Steps

Given the outputs and findings of the project, a number of next steps are planned in 2016 and 2017 as part of the ongoing EECB work with the brick sector. These include:

- Release of the guidelines through the CBA website;
- Availability for industry to access the thermal energy tool through the CBA website (could include training to brick companies of the tool);
- Release of funding calls for a series of best practice demonstrations by the EECB in early 2016 for completion by the end of 2016;
- Dissemination of the findings of the demonstrations in 2017, including case studies, events and other support;
- A report in 2016 highlighting the available funding mechanisms available for the best practice identified in these guidelines, such as bank debt, project financing, government schemes, 12L tax incentives, etc.

Further communication around these activities will come from the EECB and the CBA.

8. Appendices

8.1. Workshops

Through the project, two workshops were held in October 2015 to present the findings of the project. Participants were asked to:

- 1) Prioritise the list of energy saving opportunities and choose their top five;
- 2) Discuss the selected opportunities in groups, in order to understand:
 - o What makes this best practice a good idea?
 - o What are the key barriers?
 - o Have you deployed this already and if so, what was your experience?

Feedback from participants from both workshops are summarised below.

8.1.1. Pretoria Workshop

26 people, including 13 brick companies, attended the Pretoria Workshop on the 28th of October 2015. The workshop covered the international brick sector energy benchmarks, a presentation of the Thermal Energy Calculator, a discussion of best practices, and a presentation of current EECB activities. Participants' inputs during the best practices discussion are presented below.

- 1) Top three opportunities selected by participants in each of the five groups of best practices.

Group	Ranking	Opportunity
A (combustion & heating efficiency)	1	Use of best quality coal available locally with consistent calorific value and consistent particle size consistent with firing system in place.
	2	Addition of internal fuel (carbon) to minimise the amount of external firing of solid fuel required.
	3	Carry out ongoing daily checks on kiln burners to ensure complete combustion at point of entry.
B (brick temperature; excess air; structural losses)	1	Ensuring bricks leaving the kiln are cooled to below 100°C and the heat is recovered into the kiln or dryer.
	2	Reduce exhaust fan speed to reduce heat loss through exhaust.
	3	Improve cooling zone balance by reducing the flow through the exit contravert and the injection cooling by 10% to reduce the egress of hot air from the cooling zone into the firing zone. Use PID controller of air movement fans to maintain a constant pressure in the cooling zone and any heat recovery offtake.
C (upgrading kiln; heat recovery; energy management)	1	Use of hot air from the kiln cooling systems as preheated combustion air, for example roof space and kiln car cooling air.
	2	Replace the current clamp kiln with a fixed kiln of some kind (e.g. VSBK, Zig-Zag, TVA, Tunnel Kiln etc.).
	3	Use of recent model forklifts and optimisation of product movement. Business case on two old machines replaced by one new machine.
D (brick moisture; kiln cars; wastage; alternative materials)	1	Ensure bricks are fully dried (below 2% moisture content) prior to entering the kiln.
	2	Maintaining kiln car seals in optimum condition through planned or condition-based maintenance.
	3	Improvement of souring practice after mining through stockpiling practices.
E (power)	1	Power factor correction to reduce maximum demand charges and resistance losses.
	2	Optimising compressed air system efficiency.
	3	Convert air movement fan motors to variable speed type or fit separate variable speed drive (VSD).

2) Feedback from group discussions on eight of the selected opportunities above.

Why is it a good idea?	Key barriers	Experience
Addition of internal fuel (carbon) to minimise the amount of external firing of solid fuel required		
<ul style="list-style-type: none"> Cheaper External firing requirements reduced Aesthetics 	<ul style="list-style-type: none"> Availability Variability of product output 	<ul style="list-style-type: none"> Works well
Improvement of souring practice after mining through stockpiling practices		
<ul style="list-style-type: none"> Improves workability of clay (extrudability) Maturing the clay improves the consistency of in quality of the product eventually 	<ul style="list-style-type: none"> Working capital Planning to avoid stock outs Limited availability Moisture content variations 	<ul style="list-style-type: none"> Improves extrudability
Reducing temperature of bricks leaving the kiln to below 100°C		
<ul style="list-style-type: none"> Not wasting energy Better handling Better quality of product 	<ul style="list-style-type: none"> Length of kiln Kiln cars Money Material 	<ul style="list-style-type: none"> Experienced listed benefits
Reduce exhaust fan speed to reduce heat loss through exhaust		
<ul style="list-style-type: none"> No wasted thermal energy No wasted electricity 	<ul style="list-style-type: none"> Cost of VSDs 	<ul style="list-style-type: none"> Too long to settle
Use of best quality coal available locally with consistent calorific value and consistent particle size		
<ul style="list-style-type: none"> Closer and therefore cheaper Better quality = less coal burnt Consistent Cv = less adjustment 	<ul style="list-style-type: none"> Transport costs / availability vs distance Availability of small nut starter coal 	<ul style="list-style-type: none"> Stick with your supplier
Replace the current Clamp Kiln with a fixed kiln of some kind		
<ul style="list-style-type: none"> Reduction in production cost Quality improvement Energy efficiency improvement Waste reduction Reduction in labour 	<ul style="list-style-type: none"> High initial capital expenditure Technical know-how Product type/cost/selling 	<ul style="list-style-type: none"> No
Ensure bricks are fully dried prior to entering the kiln		
<ul style="list-style-type: none"> Savings on fuel Better push rate Quality improvement Much less waste 	<ul style="list-style-type: none"> Cash flow Infrastructure Stock on hand 	<ul style="list-style-type: none"> Experienced listed benefits
Optimising compressed air system efficiency		
<ul style="list-style-type: none"> Compressed air is expensive Rapid payback 	<ul style="list-style-type: none"> Training/awareness of stall Continuous process 	<ul style="list-style-type: none"> Include in maintenance schedules Do repetitively Training = savings

Figure 26: Presentation at Pretoria Workshop



Figure 27: Survey presentation at Pretoria's Workshop



8.1.2. Cape Town Workshop

16 people, including nine brick companies, attended the Cape Town Workshop on the 29th October 2015, which covered the international Brick sector energy benchmarks, a presentation of the Thermal Energy Calculator, a discussion of best practices, and a presentation of current

EECB activities. Participants' inputs during the best practices discussion are presented below.

1) Top three opportunities selected by participants in each of the five groups of best practices.

Group	Ranking	Opportunity
A (combustion & heating efficiency)	1	Use of best quality coal available locally with consistent calorific value and consistent particle size consistent with firing system in place.
	2	Increasing perforation size of extruded bricks consistent with local standards to reduce firing energy requirement and improve air flow through brick setting.
	3	Addition of internal fuel (carbon) to minimise the amount of external firing of solid fuel required.
B (brick temperature; excess air; structural losses)	1	Ensuring bricks leaving the kiln are cooled to below 100°C and the heat is recovered into the kiln or dryer.
	2	Insulation of hot air pipework & ductwork. In general maintain hot air ductwork insulation levels to a minimum of 50mm for temperatures below 200°C and 100mm at higher temperatures.
	2	Ensuring all kiln walls and roofs are maintained in good condition and well insulated.
C (upgrading kiln; heat recovery; energy management)	1	Process optimisation: operate at higher throughputs at the kiln and higher operational equipment effectiveness.
	1	Rip next mining area at conclusion of mining campaign to allow natural forces (wind, rain and sun) to break down materials before mining.
	1	Use of recent model forklifts and optimisation of product movement. Business case on two old machines replaced by one new machine.
D (brick moisture; kiln cars; wastage; alternative materials)	1	Ensure bricks are fully dried (below 2% moisture content) prior to entering the kiln.
	1	Improvement of souring practice after mining through stockpiling practices.
	2	Reduce the thermal mass of kiln car decks using lightweight refractory or fibre.
E (power)	1	Motor efficiency retrofits on less efficient motors, for example from IEE1 to IEE3.
	1	Tariff optimisation through shifting operations outside of peak hours, especially during the high demand season.
	1	Convert air movement fan motors to variable speed type or fit separate variable speed drive (VSD).

2) Feedback from group discussions on eight of the selected opportunities above.

Why is it a good idea?	Key barriers	Experience
Rip new mining area earlier to allow weathering, and improvement of souring practice after mining through stockpiling practices		
<ul style="list-style-type: none"> Less green waste Higher quality clay Better extruding Better quality bricks Higher % perforations 	<ul style="list-style-type: none"> Cost of mining and storage (cash tied up on raw material) Need large storage (weathering) Remix stockpile 	<ul style="list-style-type: none"> A lot of brick yards are using advanced mining and stockpiling
Reducing temperature of bricks leaving the kiln to below 100°C and heat is recovered into the kiln/dryer		
<ul style="list-style-type: none"> Energy conservation in kiln/dryer 	<ul style="list-style-type: none"> Infrastructure expense Technology restrictions 	<ul style="list-style-type: none"> Save costs Improve profits
Ensure bricks are fully dried prior to entering the kiln		
<ul style="list-style-type: none"> Improve burning Less waste Wet brick have higher shrinkage Less firing energy 	<ul style="list-style-type: none"> If over-dry, costly Packing of wet bricks – labour issue 	<ul style="list-style-type: none"> Reduce breakages
Use of best quality coal with consistent calorific value and particle size		
<ul style="list-style-type: none"> Consistency Combustion control Yields 	<ul style="list-style-type: none"> Availability Price 	<ul style="list-style-type: none"> Better yields Quality Control
Increase perforation size		
<ul style="list-style-type: none"> Reduce weight Reduce fuel consumption Improve drying time Delivery costs 	<ul style="list-style-type: none"> Breakage – new prep plant Market resistance Not suitable for all technologies 	<ul style="list-style-type: none"> Improving burning Reduce fuel consumption
Motor efficiency retrofits on less efficient motors		
<ul style="list-style-type: none"> Only as replacement motor 	<ul style="list-style-type: none"> Too long return on investment 	<ul style="list-style-type: none"> No
Convert air movement fan motors to variable speed type or fit separate VSD		
<ul style="list-style-type: none"> Fault finding Reduce energy cost Control improvement Lower maintenance on moving parts Reduce number of parts and leakage 	<ul style="list-style-type: none"> Cost of VSD Skilled labour Additional cooling 	<ul style="list-style-type: none"> Yes

8.2. Common Energy Calculations

There are many different measurements of energy out there, which can be confusing. KWh, MJ, kcal, and BTU are all in common use in various markets and sometimes, comparing apples with apples can be tricky. Additionally, sometimes energy efficiency measurements are presented which look good at first glance, but are they really? Without getting too complex, this section will present some common energy calculation norms in South Africa as well as illustrate some common pitfalls in energy calculations.

8.2.1. Specific Energy Consumption

A universal norm in energy calculations is SEC or

Specific Energy Consumption. In South Africa, the most common unit of measurement for SEC is MJ/kg of fired, saleable product. The importance of the bold typeface words is illustrated in the following example:

A tunnel kiln operator and a clamp kiln operator want to compare their energy consumption. From his oil consumption, the tunnel kiln operator believes that his plant is using 2MJ/kg. Similarly, from the amount of coal duff added into the raw material, the clamp producer believes that his plant is using 3.5MJ/kg. Hence, at face value, it appears as if the tunnel kiln operator is only using 57% of the energy that the clamp kiln producer uses. Is this correct?

Table 18: Example of calculation of the SEC of a tunnel kiln and a clamp kiln

Measurement	Tunnel kiln	Clamp kiln	Units
Energy consumption	2	3.5	MJ/kg
% of clamp kiln energy	57.1%	100.0%	
Waste	6%	20%	
Brick weight	2.2	3.2	kg
Annual output	30,000,000	30,000,000	bricks / annum
Annual brick weight output	66,000,000	96,000,000	kg
Annual energy consumption	132,000,000	336,000,000	MJ
Annual waste kg	3,960,000	19,200,000	kg
Annual weight of saleable product	62,040,000	76,800,000	kg
SEC	2.13	4.38	MJ/kg of fired, saleable ware
% of clamp kiln SEC	48.6%	100.0%	

From the above table, the initial conclusion that the tunnel kiln uses 57% of the energy of the clamp kiln is shown to be flawed. After including waste and the actual weight of the brick, the tunnel kiln is shown to have an SEC < 49% of the clamp operator's SEC. If one considers that tunnel kiln technology usually includes dryers and that no allowance is made above for the true cost of open air drying or hack lines (diesel, labour, wastage etc.), the true picture moves even further away from the 57% initially considered.

8.2.2. Typical Energy Figures for Common South African Kilns

Table 19: Typical energy figures for common South African kilns

Kiln type	SEC (MJ/kg)	GJ/1000 BEs	Brick weight (kg)	Dryers
Clamps	3.55	11	3.1	No
Transverse arch	3.50	8.75	2.5	Yes
Tunnel kiln	2.27	5	2.2	Yes
VSBK	1.00	2.6	2.6	No

Please note that the above figures are from actual, operational plants. Undoubtedly, there are plants doing better (or worse) than the numbers presented above. However, the real numbers are intended to act as a guide towards reducing confusion for those less familiar with energy calculations.

8.2.3. Useful Conversion Factors

Table 20: Some energy conversion factors

Megajoule	1 MJ	=	947.8169879	BTU	British Thermal Unit
Megajoule	1 MJ	=	238845.9	Cal	Calorie
Megajoule	1 MJ	=	238.8459	kcal	Kilocalorie
Megajoule	1 MJ	=	1000	kJ	Kilojoule
Megajoule	1 MJ	=	0.27777778	kWh	Kilowatt hour
Gigajoule	1 GJ	=	1000	MJ	Megajoule
British Thermal Unit	1 BTU	=	0.001055056	MJ	Megajoule
British Thermal Unit	1 BTU	=	1.055056	kJ	Kilojoule
Kilocalorie	1 kcal	=	0.0041868	MJ	Megajoule
Kilocalorie	1 kcal	=	4.1868	kJ	Kilojoule
Kilowatt hour	1 kWh	=	3600	kJ	Kilojoule
Kilowatt hour	1 kWh	=	3.6	MJ	Megajoule

8.3. Description of Kiln Technologies

Like in other parts of the world, South Africa uses a number of different types of kiln for the firing of clay bricks. The kiln types are grouped into the following categories:

Continuous Kilns:

- Tunnel kilns
- Vertical shaft brick kiln
- Continuous chamber & annular kilns, e.g. Hoffman, Bulls Trench Kiln & Zigzag

Intermittent Kilns

- Clamp kiln
- Chamber/shuttle kiln

8.3.1. Continuous Kilns

Continuous kilns are kilns from which continuous production is possible, i.e. a process in which bricks are continuously being added and removed.

a) Tunnel kiln

A tunnel kiln is a long heated chamber through which clay bricks are transported usually on trucks known as kiln cars.

The temperature is kept constant within each section of the kiln and as the bricks move through they are heated and cooled at the required rate. The use of multiple burners in the firing zone of the kiln and the control of air movement into and out of the kiln makes accurate temperature control of each part of the kiln possible and thus the bricks manufactured are of a high and consistent quality. The degree of combustion and temperature control makes it possible to change the temperature and atmosphere control within the tunnel kiln so that different products from different clay types can be manufactured within a tunnel kiln. Tunnel kilns are capable of high production rates of over 1 million/week and are normally automated, with a low labour requirement to operate. Tunnel kilns can utilise coal, oil and gas as fuels, with all kiln the control of combustion and temperature is easier with gas and oil than solid fuels such as coal and bio-mass.

Tunnel kilns are very energy efficient as the cold air used for cooling the bricks can be recovered for use within the kiln itself or dry bricks by directed the hot air to a separate drying chamber. A simplified schematic of the process and of the heating profile within the kiln are shown in figure 28.

Figure 28: Tunnel kiln schematic 1

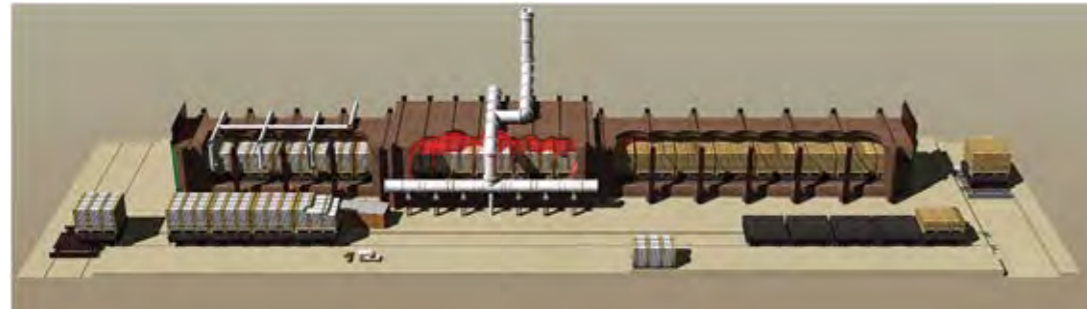
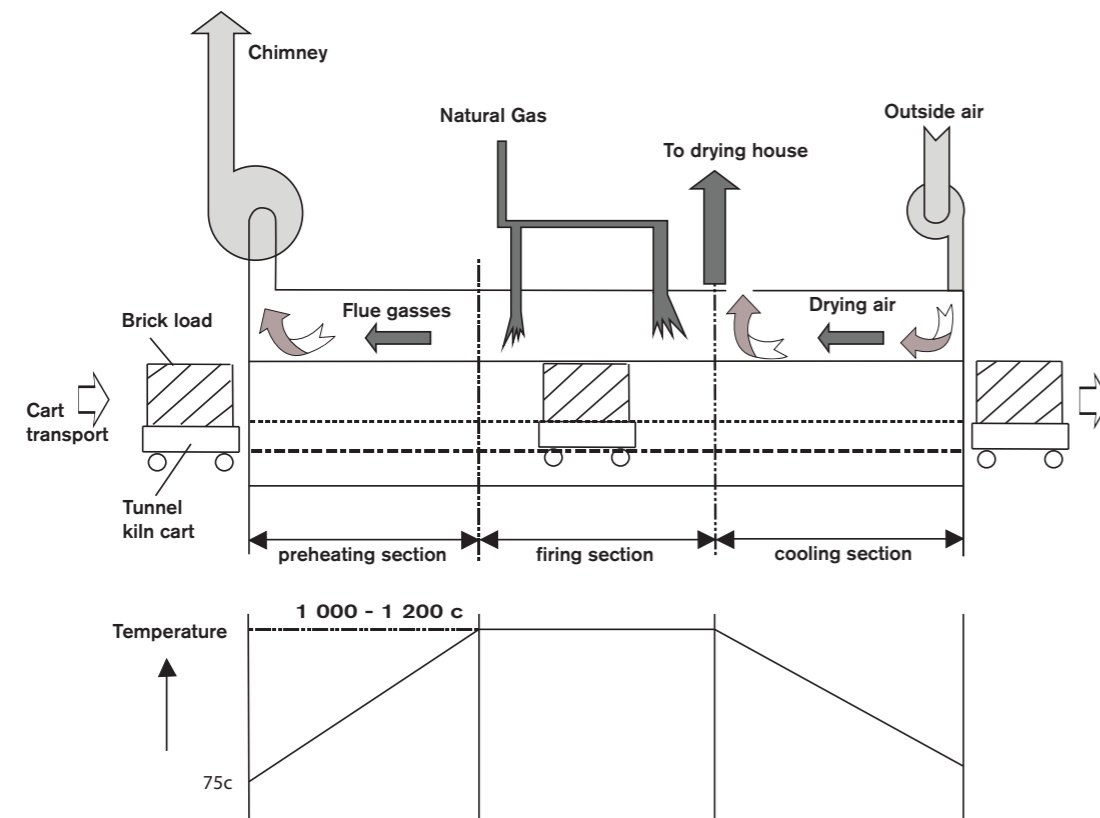


Figure 29: Tunnel kiln schematic 2



In South Africa, the kiln technology is the second most commonly deployed. Worldwide, tunnel kilns are used to produce top quality facing bricks and by virtue of the process control that their design enables. Tunnel kilns can supply 'waste' heat for drying purposes which generally means that drying is mechanised and independent of weather conditions.

Tunnel kiln technology is also much better suited to automation, can produce higher quality products and generally has health and safety advantages over most of the simpler alternatives. Nevertheless, tunnel kiln technology requires large capital investment, typically 10 – 20 times more than simpler technologies (Greentech Knowledge Solutions, New Delhi, 2012).

Figure 30: Tunnel kiln



b) Vertical Shaft Brick Kiln

The principle of a Vertical Shaft Brick Kiln (VSBK) is very similar to the tunnel kiln in that they enable continuous production via the continuous adding and removal of bricks to the kiln. They are, in effect, a vertical tunnel kiln but there are a number of differences. In general a VSBK relies on the combustion of coal added between the layers of bricks although they can also be fired with gas or oil burners.

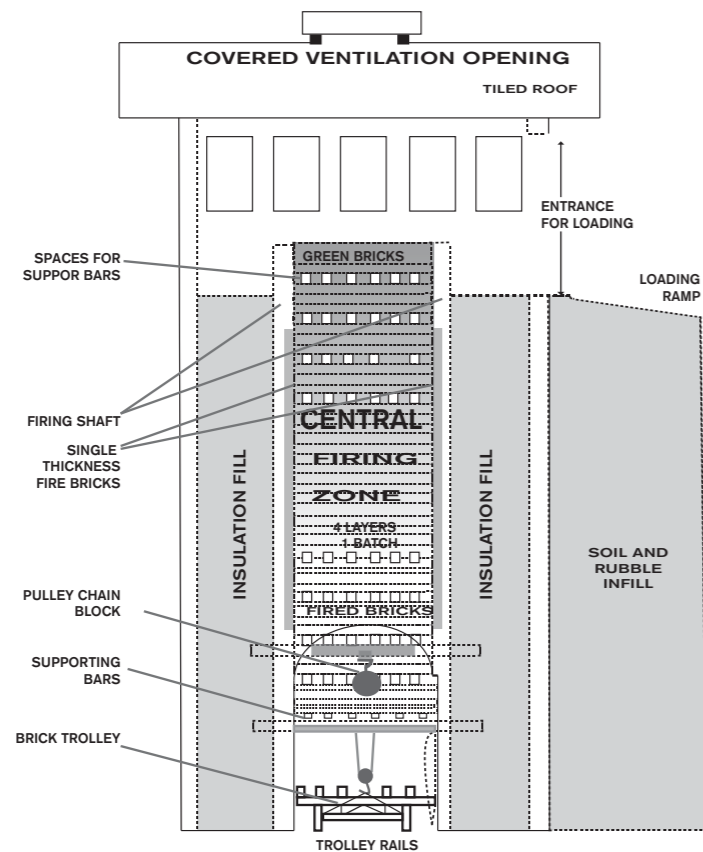
It has lower control of the air flow within the kiln than a tunnel kiln and it relies on gravity to move the bricks through the kiln. The control of combustion relies of the skilful placement of fuel within the brick setting, as the bricks are stacked at the kiln entrance and via the control of air entering and leaving the kiln.

As a vertical kiln the VSBK acts as a chimney has a high natural draught meaning that an exhaust fan is not necessary as with a tunnel kiln, this is a considerable advantage when electricity is

not available or is unreliable. VSBKs are shorter (measured from bottom to top) than tunnel kilns (measured from end to end) as bricks in the lower layers have to withstand the weight of all the bricks above, even so a higher incidence of mechanical damage is to be expected. The relative short length of the VSBK also means that heating rates and cooling rates are higher and this increases the risk of cracking during these phases of the firing cycle. VSBKs are capable of being very efficient especially if a skilled operator controls air flow into the kiln, through the setting and out of the exhaust. The thick permanent walls can be well insulated minimising heat losses through them. The independence of a power supply is also a great advantage.

A schematic of a VSBK is shown in figure 31. For high production rates, a number of VSBK would be required as alone they cannot achieve the high outputs of tunnel kilns.

Figure 31: Vertical Shaft Brick Kiln (VSBK) schematic



c) Continuous and Annular Chamber Kilns

Continuous Chamber and Annular Kilns are the third type of continuous kiln. Whereas tunnel and VSBK rely on a constant temperature profile through the structure with the bricks passing through it, bricks in continuous chamber and annular kilns remain stationary and the temperature moves around the kiln. Whilst a number of chambers are cooling the hot air from these is providing combustion air for the chambers that are in their firing phase, the hot gases from these chambers then move on to preheat dry bricks. In this way the heat of firing is recuperated enabling these kilns to be thermally efficient even though each chamber is being fired as an intermittent chamber. Continuous chamber kilns are normally fired using solid fuel, either incorporated into the brick setting or via ports in the roof at the appropriate time in the schedule. Control of air flow is provided via a chimney, usually of sufficient height to provide sufficient draught for a number of interlinked chambers, alternatively

fans can be used to control airflow but require a reliable power supply.

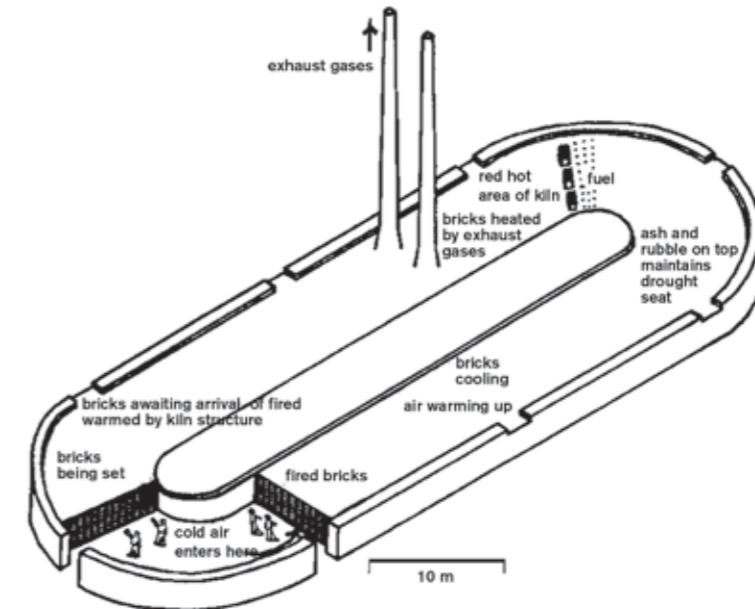
Continuous chamber kilns can vary in size greatly and are capable of the same levels of output as tunnel kilns.

There are number of variations of continuous chamber or annular kilns the main ones are summarised below.

- **Bull's Trench Kiln (BTK)**

There are two main types of Bull's Trench Kiln – fixed chimney (FCBTK) and movable chimney (MCBTK). The moveable chimney provides less control over air movement and consequently is less efficient and causes higher pollution levels. The kiln is one annular chamber with bricks added and removed at the cold ends of the process as shown in the diagram.

Figure 32: Bulls Trench Kiln schematic



- **Hoffman Kiln**

Hoffman Kilns are similar to the BTK design in that the bricks are set within a large annular chamber. The main differences are that the individual chambers can be separated using permanent brick wall and that all the chambers are connected via a central flue leading to a fixed chimney. Hoffman kilns also have a permanent roof through which fuel can be added to the firing zone, giving further control over the combustion process that fires the bricks.

- **Zig-Zag Kiln**

A Zig-zag kiln is a variation of the Hoffman kiln, in that the stacking of the bricks follows a Zig-Zag pattern - in effect lengthening the route the air takes through the setting tacking, thus helping with combustion and heat recuperation. While some utilise a natural draft, others use a fan to draw the fire and heat through the Zig-Zag stacking pattern. This firing process requires a set of highly trained and skilled workers to operate and maintain the kiln.

Figure 33: Hoffman kiln schematic

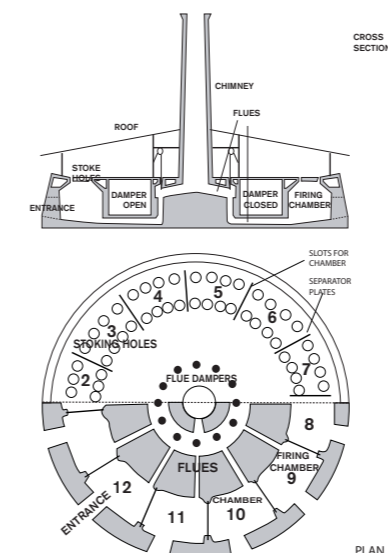


Figure 34: Zig-Zag kiln schematic



Most operators examining their kiln during the firing will be able to assess where the key heat losses are using the heat balance, and determine an accurate, specific energy consumption for their kiln. Nevertheless there are some instruments that are widely available, easy to use and extremely useful in improving the performance of a kiln. These are thermocouples for measuring temperatures, bullers rings for measuring the peak temperature throughout the firing, and a combustion analyser for measuring the oxygen and carbon monoxide (CO) content of exhaust gases. Coupled with this, should be a record keeping system that measures the overall “quality” of each firing and thus promotes the continual improvement of quality and lower energy costs. Based on these accurate measurements, plant managers can identify a number of relevant best practices for their kiln in the long list of opportunities in Chapter 6.

8.3.2. Intermittent Kilns

a) Chamber & Shuttle Kilns

Chamber kilns are enclosed structures within which bricks are heated and cooled. They operate alone as a batch process and as a result much of the heat is wasted through the exhaust even when deploying heat recovery technology in the exhaust stack or through the use of recuperative burners. Chamber kilns can utilise any type of fuel and can operate under natural draught or forced draught.

Figure 35: Intermittent Chamber kiln.



Chamber kilns are much cheaper to than tunnel kilns and easier to operate and maintain but are less thermally efficient as there is little to no heat recovery from the hot gases. Improvements in thermal efficiency can be made by incorporating suitable fuel into the brick body recipe and by linking the exhaust flues of multiple chambers together so that the hot air exhausted during cooling can be used within the other chambers.

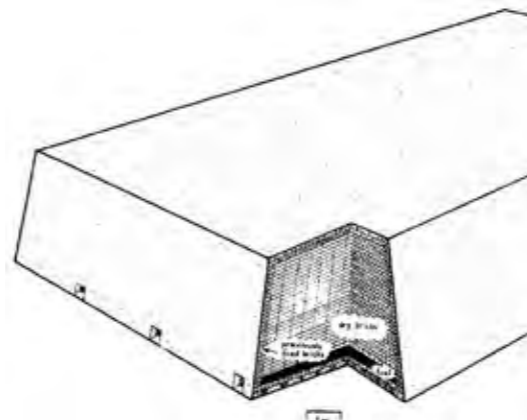
b) Clamp Kiln

Clamp kiln is a term used for a wide variety of rudimentary kilns that use solid fuels, such as coal, either contained within the brick or laid between layers of bricks. The bricks are stacked with spaces and channels so that combustion air can reach the fuel, as well as for exhaust gases to leave the clamp. The clamp may either have permanent walls to contain the bricks or be covered with reject bricks and an outer layer of clay or plaster.

Firing of a clamp requires a great deal of experience and because of the relatively uncontrolled burning than takes place, the quality and size of the fired bricks can vary greatly. Product waste levels are high, as are pollution levels for the workforce and the wider environment. Clamp kilns can be more efficient than chamber kilns, due to their greater size and the common practice of incorporating fuel into the body recipe.

Clamps do not require a permanent structure, making them extremely versatile and easy to install and maintain.

Figure 36: Clamp kiln schematic



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