3rd Edition

MANUAL

ENERGY EFFICIENCY IN THE BRICK INDUSTRY

PROGRAMA DE EFICIENCIA ENERGÉTICA EN LADRILLERAS DE AMÉRICA LATINA PARA MITIGAR EL CAMBIO CLIMÁTICO – EELA

(Energy Efficiency Programme in the Brick Sector in Latin American to Mitigate Climate Change – EELA)

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PRESENTATION

The Latin American Brickworks Energy Efficiency Programme to Mitigate Climate Change (EELA) seeks to contribute to a reduction in greenhouse gas (GHG) emissions in the brickworks industry of Latin America (LA) and improve quality of life for the population involved. This program is financed by the Swiss Agency for Development and Cooperation (COSUDE, per the Spanish acronym) and executed by Swisscontact with its partners in seven countries: Argentina, Bolivia, Brazil, Colombia, Ecuador, Mexico and Peru.

This Manual on Energy Efficiency is part of a set of tools and instruments seeking to provide companies with technical information for more energy efficient, cleaner and more sustainable production.

The text is divided into seven principal parts where different alternatives are presented to reduce companies' energy consumption: improved combustion process, heat recovery, placement of pieces within the kiln, use of residue in the ceramic dough (pug), thermal insulation, use of ceramic nozzles, use of more efficient kilns. This set of technical measures, besides providing a savings in thermal energy, also leads to improved product quality, reducing production losses.

Finally, the concept of specific energy consumption and an example that helps company owners to better understand the efficiency of their production processes and effective costs in energy is presented in the appendix.

Contents

1| INTRODUCTION

This manual presents concepts and technical information about efficient kiln performance for the brickworks industry, including concepts and data related to energy use and final product quality.

The technical information included in this manual arises from the experience obtained in the framework of the EELA Programme activities. Results obtained from kiln operation reveal different positive aspects like reduction in fuel consumption, which represents a reduction of GHG emissions by using these models of energy efficient kilns. This savings represents improvements in productivity and competitiveness for brickworks companies as well as improvement in the quality of the final product.

2| ENERGY EFFICIENCY

The concept of energy efficiency is related to the optimum use of energy resources without modifying brick industry production, seeking to explore various possibilities to reduce energy consumption that also represent economic and environmental advantages.

Energy efficiency can comprise simple and low-cost measures (thickening kiln walls, re-arrangement of bricks inside the kiln, etc.) to other more complex and expensive measures (like the change to highly efficient continuous kilns). Therefore the greater use of more efficient techniques, equipment and processes leads to less energy consumption and consequently fewer expenses for this resource.

A very simple and common way to determine how a brick company's efficiency can know its specific energy consumption, either from the fuel consumption or the electricity consumption, and then compare it to other companies that have the same type of production.

This specific energy consumption is calculated by the relation between the energy consumption (e.g., firewood consumption), divided by production (reported in thousand pieces or in tonnes) to obtain an indicator that will show us whether the company is making efficient use of energy and tell us how many potential producers would be possible to support for the improvement compared to current production.

Thus, knowing that it is possible to save energy, it is important to evaluate some other technological alternatives and options in relation to the kiln type, as presented below, so that producers can chose the kiln model that meets their expectations regarding the improvement in their production process.

3| EFFICIENT USE OF ENERGY

Sometimes the technological measures proposed for efficient energy use can appear as economically unfeasible or impossible to apply. In practice this is not so certain because some measures can attain additional achievements associated with energy saving, which finally is a great benefit for the brick maker. This is the case for technical measures that can benefit not just with savings in energy and/or fuel consumption, but also in the increase in number of bricks produced, reduction in losses per lot of bricks produced and, in some cases, even an increase in the production of first quality pieces as well as the possibility to produce new products or higher value pieces.

Therefore, when thinking about investing in the implementation of energy efficiency actions and projects it is important to take account of all these benefits. In any event, implementation of projects and modifications in a company must be preceded by a careful evaluation of the advantages and possible disadvantages of the technologies. In the case of kilns, the heat produced by combustion is distributed to several points but only one part is used to fire bricks and/or roof tiles. The majority of the heat is lost in combustion gases (smoke) which is emitted from the kiln through the chimney while another part is stored in the walls and roof (or dome) and the remainder in the fired products themselves. This is considered a heat loss. Figure 1 shows the heat distribution during the firing process.

Figure 1 Heat flow in brick production kilns

[insert figure 1. flujo de calor en hornos de producción de ladrillos]

Pérdidas de calor en horno=Heat loss in the kiln

The numbers in the figure indicate the different situates related to heat loss:

a. Heat supply/fuel combustion
b. Heat loss in combustion gases/chimney
c. Losses through openings and cracks
d. Loss through walls and roof/dome
e. Heat accumulated in kiln walls
f. Heat accumulated in pieces produced
g. Useful heat absorbed by the pieces fired

Firing pieces in the kiln is the principal phase of the product manufacturing process in terms of energy, generally making use of 95% of all the thermal energy required by the company. The remaining 5% is related to the drying process only at those companies that have implemented that process.

Therefore, ideally production should use the least amount of energy possible, which can be achieved by allowing less heat loss through the points identified in the above figure or alternatively by trying to recover this heat to use it in the production process, as in the case of drying the pieces in a closed area.

Comentado [PT1]: Corregir nomenclatura en la figura original ya que sale con numeros y las referencioas estan con letras:

1=a
2=b
3=c
4=d
5=e
6=f
7=g

3.1. IMPROVED COMBUSTION

Good combustion is important for good kiln operation and to generate quality products. This process transforms the chemical energy of the fuel into heat that in turn is transmitted to the load processed (roof tiles, bricks or floor tiles).

Good combustion demands a lot of care, but it must begin with correct sizing of the burners or combustion chambers (volume and type of chamber according to type of fuel and the load to be processed). For example, a very small combustion chamber fed with a lot of firewood may not receive enough air for good burning while generating a lot of soot and wasted energy.

Therefore, each type of fuel (firewood, oil, or gas) should involve a specific burner to achieve well-directed and –balanced combustion (without waste and without soot).

[Insertar Esquema de combustión]

Leña=firewood; Aire=air; Calor/Energía Térmica=heat/thermal energy
Combustible=Fuel; Oxígeno=Oxygen; Esquema de combustión=Combustion Diagram

Burning should be controlled ideally by monitoring the amount of air present in combustion. This can be done by testing for CO_2 (carbon dioxide) or O_2 (oxygen), but since this is difficult in daily work, it is better to use continuous fuel feeding and observe the intensity of the automatic fuel feeder, radiation of flames and whether or not there is soot in the chimney. Excessive soot equals bad combustion due to lack of air and the consequent loss of energy. Continuous feeing reduces fluctuations in combustion and guarantees better use of heat produced by burning.

[espacio para insertar la figura: Alimentador automático de combustible]

Alimentador automático de combustible=Automatic fuel feeder

In addition to correct sizing of the combustion chambers, combustion control and the most continuous feeding possible, air injection and the use of cut firewood or sawdust can be quite helpful.

3.1.1. USE OF FORCED AIR (AIR INJECTION)

Injecting combustion air with ventilators (forced air), when it is well operated, can reduce the firing time and fuel use by around 30% as well as improving product quality due to adequate heat supply to the kiln load.

[Espacio para la figura: Inyección de aire de combustión

Inyección de aire de combustión=Combustion air injection

This solution can reduce frequent problems with poor heat distribution in kilns, avoiding burning with yellow flame which indicates inefficient combustion. Obviously electricity will be used by the ventilators, but it may be compensated by saving on firewood.

3.1.2 USE OF CUT FIREWOOD

[Espacio para la figura: no tiene título per es de leña]

The shape of the firewood or biomass residue (trunks, branches, chips, etc.) used as fuel interferes a lot in the combustion process. The smaller the fuel (chips or sawdust) the easier the burning and less combustion air required; the less amount of combustion air (watching minimum limits) the less heat loss through the flue gases, and the process will be more economical. Likewise, the presence of moisture in the fuel (very wet firewood) undermines the combustion process. The smaller the fuel, the more quickly and easily moisture is released, so burning is not impeded because combustion heat is not necessary to dry it. Thus, when the firewood is cut up, the percentage of moisture in combustion is immediately reduced; the demand for air to burn the fuel is lower resulting in immediate reduction in heat loss in the combustion process.

Using cut firewood can provide up to a 20% savings in fuel use. Chips or sawdust can be supplied by feeders which provide homogeneous combustion without emitting soot.

[Figura en la siguiente página: Comparativo entre leña en leños o troncos y leña trozada]

Aire de combustión con exceso do 90%=Combustion air with 90% excess; Aire de combustión con exceso de 40%=Combustion air with 40% excess; Reducción del consumo de leña de 20%=Firewood consumption reduced by 20%; Comparativo entre leña en leños o troncos y leña trozada=Comparison between firewood in trunks and cut firewood

3.2 HEAT RECOVERY

Even the best brick production kilns generally present from 30 to 60% heat loss through extraction gases as well as the cooling phase. Therefore, it leads to a very high proportion that could be used in many situations.

[Espacio para la figura: Ejemplo de secado de piezas en estufa (secador)]

Example of drying pieces in the dryer

Typical possible recovery is use in heaters or dryers for green pieces or to preheat the load before firing. One or the other type of use is possible in each type of kiln leading to savings of from 15% to 30%.

3.2.1. RECOVERY FOR THE DRYER

Heat recovery in ceramic kilns for drying pieces is quite a common practice. Several types of kilns allow hot air from the cooling phase to be recovered to use in the drying kiln (*estufa*).

This procedure is done by injecting cold air through the chamber doors in the kiln once firing is complete; hot air is removed through ducts with the aid of an extractor.

The greatest challenge in this type of initiative is to combine the continuous operation of a dryer with the operation of the kiln which generally is not continuous. The way to achieve that is complementing the heat necessary by installing an auxiliary burner.

[Insertar figura: Diseño de la recuperación de calor para estufa (secador)]

Estufa=Dryer; Aire caliente=Hot air; Inyección de aire=Air injection; Válvula compuerta cerrada=Closed damper valve; Chimenea=Chimney; Horno=Kiln; Válvula compuerta abierta=Open damper valve; Precalentando=preheating; Quemando=Firing; Gases calientes de combustión=Hot combustion gases.

3.2.2. RECOVERY FOR THE KILN

This process is used in some types of kilns where it is possible to cross-connect the chambers and even the kilns themselves. Thus it is possible to preheat the products in one chamber that still has not been fired using hot gas from the chamber which is being fired.

Heat recovery can be used in chamber type kilns like the *paulistinha*, dome, Hoffmann, CEDAN, and others. Care must be taken in intermittent kilns (by lots), for example the *abóvedado* (dome circular), not to interfere negatively with burning in the kiln that is operating where temperature control should be well-monitored.

[Figure: sin título]

Estufa=Dryer; Válvula compuerta cerrada=Closed damper valve; Chimenea=Chimney; Horno=Kiln; Válvula compuerta abierta=Open damper valve; Precalentando=preheating; Quemando=Firing; Gases calientes de combustión=Hot combustion gases.

3.3. ARRANGEMENT OF PIECES IN THE KILNS

The arrangement of the ceramic pieces inside the kilns is very important, not just for good firing efficiency, but also to achieve a greater ratio of first quality, more uniform products.

Products should be arranged and aligned in a way that combustion gases may circulate well between the ceramic pieces so that the exchange of heat is more homogeneous with the load in the kiln, achieving the correct firing temperature and the time necessary for product sinterisation.

The reduction in energy consumption and operating time can be on the order of 5%, and the increase in first quality pieces can be even greater, remembering that this procedure does not require an investment cost, just a change in arranging the pieces inside the kiln.

(Imagen a la izquierda) [Image on the left] Traditional arrangement of roof tiles always in the same position (compacted) and with no spaces for hot gas to pass.

(Imagen a la derecha) [Image on the right] Proposed arrangement with spaces for hot gas to pass

3.4 USE OF WASTE IN THE CERAMIC MIX (DOUGH)

Some types of agricultural and industrial residue may be used in producing bricks. This residue can be: crushed coal, pet-coke, sawdust, paper fibre, waste oil, and the like. These materials are mixed with the ceramic mix in ratios from 1% to 5% by weight, depending on type of waste. This procedure does not apply for roof tile manufacture, since it generally causes an increase in porosity of the ceramic piece and moisture absorption.

The savings in fuel used can vary from 10% to 15%, and product quality may improve, especially mechanical resistance. Savings can also be realised from lower electricity use by the extruder/press since the raw clay is more mouldable.

[Insert figure: esquema de residuos en la masa cerámica]

Diagram of waste in ceramic dough

HORNO=kiln; arcilla=clay; carbón triturado=crushed coal; agua=water; boquilla=nozzle; corte=cut; secado=drying; extrusora (reducción de 3% - potencia eléctrica)=extruder (3% reduction in electricity use); reducción de 10% a 15% del consumo de leña=10% to 15% reduction in firewood use.-

3.5 IMPROVEMENT IN THERMAL INSULATION

Kiln efficiency can improve with the use of adequate thermal insulation seeking to reduce heat loss from radiation and convection in the kiln walls and roof. These losses can reach percentages up to 30% of all thermal energy provided from burning fuel.

Thermal insulation is achieved by using outside layers of insulating bricks after the internal refractory layers. Blankets and ceramic fibre can also be used inside some kilns, primarily those where there is no physical contact with employees and materials.

Finally, adequate sizing of the walls and perfect seal on doors and burners also contribute to greater energy savings. The savings obtained by using appropriate insulating material is quite variable, but it can represent between 5 and 12% of fuel consumption.

[Insert figure "Como mejorar el Aislamiento Térmico"]

How to improve Thermal Insulation

Cara interna del horno=Inside face of kiln; Cara externa del horno=Outside face of kiln; Pared de ladrillo macizo=Solid brick wall; Fibra Cerámica=Ceramic fibre.

3.6 USE OF HARD CERAMIC NOZZLES

Over time, the steel extrusion profile of the extruder wears from friction with clay silicates, which leads to an increase in piece size. The result is a gradual increase in clay consumption (heavier pieces over time) as well as use of electricity for the extruder motor and heat in the chambers and kilns.

Another negative point caused by accentuated wear on traditional steel nozzles is the change in product dimensions, leaving them outside of technical specifications. In addition, the profile change requires an interruption in the production process which causes an increase in cost for the company.

Accordingly, it is very important to reduce the frequency of interruptions and the previously mentioned losses. This can be achieved by using hard ceramic profiles like alumina or zirconium that experience less wear and thus produce for a longer time within the technical standards, besides saving energy.

[Insert image: perfiles]

Source: Duracer

3.7 USE OF MORE EFFICIENT KILNS

Different kiln technologies are available in the brick production industry, many of them since colonial times, as is the case of campaign kilns (*caieira*) and *caipira* (open kiln with fixed walls), with extremely high (over 1 000 Kcal/kg) specific energy consumption indices and low energy efficiency (less than 25%).

[Figura del horno caipira] *Caipira* kiln

That is, even today there are kilns in operation with heat losses representing at least 75% of the total energy provided by the fuel.

It should be noted that some kilns can apparently have less specific consumption of firewood, but this is not exact. It depends on the variable ratio between production of first and second quality pieces (or pieces that do not meet quality standards).

KILNS		***Caipira***	***Paulistinha***	***Abovedado***	**Hoffmann**	**Cedan**	**Portable Metal**	**Tunnel**
Specific Firewood Consumption (st/thousand)		1,2 to 1,5	1,25 to 1,7	1,15 to 1,6	0,9 to 1,2	0,6 to 0,7	0,7 to 0,8	0,6 to 0,65
Energy Consumption (Kcal/kg)	*lower*	795	583	536	418	409	397	341
	higher	1104	914	860	637	545	519	422
Average capacity per	*thousands*	23 to 40	30 to 60	60 to 110	35/chamber	28/chamber	50 to 120	100 to 130 tonne/day
1st Quality pieces	*average (%)*	20 to 40	50 to 70	60 to 80	90	90	90	95
Thermal efficiency	*average (%)*	27	35	38	50	54	56	66
Production Losses	*average (%)*	10 to 20	5 to 8	2 to 5	<2	<2	<1	<1
Products		Te/La	Te/La/Ba/LH	Te/La/Ba	Te/La/Ba/LH	Te/La/Ba/LH	Te/La/Ba/LH	Te/La/Ba/LH
Heat Recovery	*Yes/No*	No	Yes	Yes	Yes	Yes	Yes	Yes
Soot Emission		Considerable	Little	Little	Very little	Very little	Very little	Very little
Cost	*US$ thousands*	8.3 to 10	33 to 50	33 to 50	250 to 283	133 to 166	150 to 183	366 to 433

Caipira: Open kiln with fixed walls. Abovedado: Dome circular
Te: Roof tile; La: Brick; Ba: Floor tile; LH: Hollow brick
Using 3 650 kcal/kg as the base firewood calorific value, a variable mass of 1 240 to 2 500 kg of ceramic products per thousand, allowing fuel biomass variability between 225 and 320 kg per stere and the assumption that useful heat for firing 1.0 kg of ceramic material is 250 kcal, according to the assumptions of each type of kiln.

Intermittent kilns (by lots) are used in many places, but have a higher technological level, like the *Paulistinha* and *abovedado* (dome circular) where specific energy consumption values are in the range of 550 to 1,000 kcal/kg (thermal efficiency between 30% and 40%).

Semi-continuous kilns are in the previous category, like the Hoffmann, Cedan, and their other adaptations as well as the portable metal kilns, with specific energy consumption between 400 and 650 kcal/kg and thermal efficiency between 45% and 55%.

The leader of the most efficient is the continuous kiln, like the tunnel kiln, with specific energy consumption values between 330 and 450 kcal/kg and energy efficiency between 55% and 70%.

[insert photos of Horno Cedan and Horno abovedado o redondo]

Horno cedan=Cedan Kiln; horno abovedado o redondo=abovedado or circular kiln.

[insert photo of Horno Hoffmann]

Horno Hoffmann=Hoffmann Kiln

[Insert photos of Horno Túnel and Horno metálico móvil]

Horno Túnel=Tunnel kiln; Horno metálico móvil=Portable metal kiln

However, the advantages of some kilns are not restricted only to the energy use; several types can yield a larger number of first quality products and lower production losses.

Atmospheric emissions can also be a significant issue to keep in mind, particularly as relates to particulate material (soot). The countries' governmental environmental institutions are taking more actions to control these emissions. In some countries, brick making kiln emissions are controlled with maximum limit values; emissions have to be monitored periodically by specialised services.

Some kilns cannot meet these requirements, like the open kilns without chimneys, and even with chimneys some types of kilns emit a lot of soot, principally when they are fed with firewood, due to lack of combustion air in the kilns. A measure that can help mitigate or resolve this problem is the use of cut up firewood with continuous feeders, which will mitigate the lack of combustion air, reducing the appearance of soot. It is also possible to connect gas scrubber systems in these kilns.

Continuous or semi-continuous kilns tend to emit less soot because their internal architecture, where combustion gases change direction, leads to conditions for the particulate material to be deposited inside, without reaching the chimneys. The material deposited (soot and ashes) must be removed every so often from the internal channels in the kilns as part of maintenance.

APPENDIX 1. SPECIFIC USE OF ENERGY

Specific energy consumption is a highly important index in assessing energy performance of an industry or of its phases of production process and even its principal equipment. It is also important in assessing the results of implementing energy efficiency measures (fuel and electricity) so that results can be compared before and after applying a new project or equipment. The evolution of specific energy consumption values over time allows follow-up of energy performance and comparison with other companies. These values also make it possible to compare different technologies, for example, the different types of existing kilns. For this, it is necessary to correctly establish these indices with detailed measurements.

Specific energy consumption refers to the amount of electric or thermal energy used in manufacturing a determined product. Some types of specific energy consumption indices that can be established in the company are shown below.

THERMAL ENERGY

Stere (st) or cubic metre (m^3) or kg of firewood per tonne (t) of final product or per thousand (1 000 pieces). Ideally the control unit should be Kcal/kg of final product, but this requires that units be converted, as shown in the example presented later.

ELECTRIC ENERGY

kWh/t of clay processed or kWh/t of product leaving the kiln or kWh/t of final product (discounting the losses). Although we have a monthly use measure (kWh) for electricity reported on the electric utility bill, for firewood and other types of biomass (agricultural and industrial waste) a more careful analysis would be required.

The sale of biomass is by the t (tonne) or st (stere) – a unit that considers the volume of 1 m^3, but with the possibility of large variations in mass based on the variation of the shape of firewood (presence of branches, average diameter). The energy content is also influenced by the type of wood used and the amount of moisture. So, the mass of a stere of firewood can vary generally from 150 to 400 kg, evaluating the specific energy consumption of a manufacturing process based on the volume in st is completely inaccurate since it is necessary to convert this measurement in steres to a fuel mass (kg or t).

In summary, specific thermal energy consumption control using the traditional index of st or m^3 of firewood/thousand produced should be avoided, considering the large possible variations in firewood mass per st or m^3, as well as the product mass per thousand. Ideally, the firewood used should be weighed (sample weight) and production obtained (calculation of mass produced) giving values in kg (or tonnes) of firewood per kg (or tonne) of production. The values necessary to calculate the specific energy consumption should be reliable and strictly measured. In addition, some necessary information may be obtained from technical tables that the manufacturer should have available, like those shown below.

Table 1. Lower calorific value (LCV) of different biomasses

Biomass	LCV	Biomass	LCV
Firewood (40% water)	2 400	Huasai palm seed	2 400
Dry firewood (12% water)	3 680	Brazil nut shells	2 400

Eucalyptus branches	4 300	Huahuasú palm bark	2 400
Eucalyptus	3 800	Cashew nut shells	2 400
Pine cones	4 000	*Mimosa tenuiflora*	2 400
Dry sawdust (20% water)	3 500	*Caesalpinia pyramidalis*	2 400
Sawdust/bagasse briquette (50/50)	4 430	*Acacia angico*	2 400
Bagasse (20% water)	3 200	Algarrobo	2 400
Rice husks (12% water)	3 300	Cashew tree trimmings	2 400
Cocoa husks	4 000	Charcoal	2 400

LCV: Lower Calorific value (Kcal/kg)

Table 2. Biomass moisture vs. Lower Calorific Value (LCV)

Moisture %	LCV	Moisture %	LCV
0	4 756	50	2 085
10	4 221	60	1 551
20	3 687	70	1 016
30	3 153	80	482
40	2 619	90	-

If information is not available about the specific mass of the firewood or biomass residue (kg/m^3), the business owner should weigh the firewood to be used in the factory (for example weigh from 3 to 6 cubic metres).

APPENDIX II. EXAMPLE OF SPECIFIC ENERGY CONSUMPTION CALCULATION

A company produces 1 000 thousand/month with 40% roof tiles (1,1 kg/piece) and 60% hollow bricks (1,8 kg/piece). This means that the company produces 400 thousand/month of roof tiles (440 tonnes/month) and 600 thousand/month of hollow bricks (1 080 tonnes/month) resulting in a total production of 1 520 tonnes/month. Therefore, the percentages indicate a final production mass ratio of 71% hollow bricks and 29% roof tiles.

If the company uses 1 000 m^3 of firewood (1,0 m^3 of firewood per thousand) per month with a specific weight of 250 kg/m^3 or stere, it will require 250 000 kg of firewood mass (1 000 x 250) for that month. So now we have a consumption ratio of 250 tonnes of firewood per 1 520 tonnes of production, given the specific consumption value of 0,164 t of firewood/tonne of product (250 000 ÷ 1 520).

If this firewood has a specific consumption value of 3 000 Kcal/kg (see table for type of firewood), it means that the company needed 750 million Kcal (= 250 000 kg x 3 000 Kcal/kg). If we divide this value by the monthly production in kg (1,520,000 kg), we obtain the specific thermal energy consumption of 493 Kcal/kg which should be the reference value for the company to verify its thermal energy performance periodically.

Firewood consumption of the dryer, if there is one, can be added to the calculation, making the index even more realistic and precise. So, if the firewood consumption in the kiln were 50 m^3/month, the total firewood consumption for the company would be 1 050 m^3/month and, following the previous logic, we would obtain a specific thermal energy consumption of 518 Kcal/kg. Thus, with this reference value, the company can monitor its fuel consumption weekly or monthly or even compare it with competitors or partners.

Other similar indices can be established referring to the mass of clay processed or final production less losses, since they will all enable a more analytic reading of the energy operation over time