TEN RULES FOR ENERGY EFFICIENT, COST EFFECTIVE BRICK FIRING

A GUIDE FOR BRICKMAKERS AND FIELD-WORKERS

Introduction

The basic ingredient of bricks is clay. The clay must be plastic when mixed with water so it can be shaped. It must then have enough 'strength' to keep its shape, and the clay particles must fuse together when fired. When bricks are fired in a kiln or clamp a ceramic bond should be formed. Depending on the type of clay, this happens at temperatures between 900 and 1,200°C. The bond gives bricks strength and resistance to erosion by water. The temperature at which bricks are fired is critical. If it's too low, the bond is poor, resulting in a weak product. If it's too high, the brick slumps or melts. So it's important that brickmakers use the right quantity of fuel. And, given that fuel is a major cost, it's important not to waste it.

Figure 1: Large clamp kiln near Kassala, Sudan. ©Practical Action/Theo Schilderman

Practical Action is working with brickmakers in a number of countries, including Peru, Ecuador, Zimbabwe, Sudan and Sri Lanka. One of Practical Action's aims is to promote appropriate, energy efficient brick firing. Most of the energy used in brickmaking is needed in firing. In some cases a lot of energy is used in drying. The brickmakers Practical Action works with are generally small-scale, artisanal or traditional producers. They face many technical and financial problems. They may have a shortage of fuel, for instance where wood has been used up. They may want to increase the quality of their bricks so they can sell to more profitable markets. Or they may simply need to cut the cost of production to be viable.

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technical brief

One thing which emerged from Practical Action's international work was the need for agreement on basic principles of energy efficient, cost effective brickmaking. These notes propose and briefly explain ten rules - good guidelines - for energy efficiency. The rules should prove useful for brickmaking on any scale with any technology. They are not presented in any sort of priority order.


Figure 2: Slopmaking in a triple mould, Zimbabwe. ©Practical Action/Theo Schilderman

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The Rules

1. Bigger kilns are more efficient

The bigger a kiln is, the smaller its surface area compared to its volume. The volume of a kiln is proportional to the number of bricks in it. Heat is lost from the surface area of a kiln. So, if this cooling area becomes proportionally less compared to the volume, more bricks are fired for relatively less heat loss.

The table below shows how the ratio of surface area to volume decreases as kilns get bigger and hence, proportionally, the reduction in the energy needed. The table is for a cubic kiln built with bricks of 230 x 110 x 70 millimetres. Cubic kilns are considered as having four cooling faces. The heat loss from the top of the kiln - in exhaust gases - and the small loss to the ground can be considered separately.

Length of side (m)	Cooling area, A (m^2)	Volume, V (m^3)	No. of bricks	Ratio A/V
2.62	27.46	18	10,000	1.53
3.30	43.56	36	20,000	1.21
4.16	69.22	72	40,000	0.96
5.24	109.83	144	80,000	0.76

Example
Señora Jara, a Peruvian brickmaker, is using 0.40 tonnes of coal to fire 1,000 bricks, 230 x 110 x 70 mm. She fires 80,000 a month in clamps of 10,000. The coal has a calorific value of 25,000 Mega Joules per tonne. A tonne costs $400. She estimates her process is 50% efficient. That is, half the energy actually fires the bricks and the rest is lost to the atmosphere. Of the 50% of energy lost, she thinks at least one-third is from the sides of the clamps. How much money could she save by burning a whole month's production in a single, large clamp?

Burning 0.40 tonnes of coal means 0.40 x 25,000 = 10,000 MJ per 1,000 bricks. So eight clamps of 10,000 bricks uses 800,000 MJ. Half this, 400,000 MJ, is lost. A third, 133,333 MJ, is lost from the walls at a cost of 133,333 MJ ÷ 25,000 MJ/tonne x 400 $/tonne = $2,133. Referring to the table, the surface area of a 10,000 brick clamp is 27.46 m^2. Eight clamps means a total cooling area of 219.68m^2 - proportional to a $2,133 loss. The surface area of an 80,000 brick kiln is 109.83m^2, around half. So this would correspond to a loss of $1,067.

What does this mean in practice? Almost 17% of waste energy is lost from clamp walls: 5.44 tonnes of coal per 80,000 bricks. If this loss is halved, the coal used can be reduced to 366 kilograms per 1,000 bricks, saving $1,088 per month.

2 Square kilns are generally more efficient than rectangular ones

A kiln with equal sides has a smaller cooling area than a rectangular one of the same volume. So efficiency is better because of reduced heat losses. From the table, a cubic kiln of 20,000 bricks has a surface area of 3.30 x 3.30 x 6 = 65.34 m^2. A rectangular kiln with the same number of bricks - the same volume - could be built by making it four times longer, halving the height and the width. That is, it would measure 13.20m x 1.65m x 1.65m. However, the surface area would be (4 x 13.20 x 1.65) + (2 x 1.65 x 1.65) = 92.57m^2. Even considering only the four 'cooling faces', the cubic kiln has a surface area of 3.30 x 3.30 x 4 = 43.56m^2, while the rectangular one is ((13.20 x 1.65 x 2) + (1.65 x 1.65 x 2)) = 48.21m^2.

3 Increasing insulation reduces heat losses

Heat is lost through the top, the walls and, to a lesser degree, the bottom of the kiln. Anything which reduces this heat loss increases efficiency. Thicker scoving, plastering with mud, on clamps will help reduce losses as will using fired bricks in the outer layers. For kilns, thicker walls or a wall with an air gap will help.

4 Placing fuel as close to the bricks as possible is most efficient

Obviously, if a brick is a long way from the heat, it will not 'burn'. So having the fuel closer to the bricks is more efficient. Placing some or all the fuel in the clay mix can be very efficient. Incorporating, for example, coal dust or saw dust into the body of bricks is an established technique. In some brickworks all the fuel needed is inside the bricks. The fuel chosen should be fine so as not to cause large voids in the bricks. Brickmakers should also try distributing their fuel more evenly throughout the kiln rather than, say, burning it all at the bottom in tunnels.

Example
How much fuel can be moulded into bricks? This varies with the clay type, the fuel type, and the burning process. Some experts suggest 5% of fuel by weight as a maximum. Señora Jara can buy coal dust of the same calorific value as her coal. It's cheaper because it's regarded as waste, so she saves money. Using bigger clamps, she needs 366 kilograms per 1,000 bricks. Her bricks weigh about 3 kilograms, so this fuel requirement corresponds to around 12% of the mass. That's probably too much to incorporate all of it into the brick, but she could try using up to half her fuel as dust in the bricks and distributing the rest of the coal, through the clamp.

5 Continuous kilns are more efficient than batch kilns

Continuous kilns typically use 'waste' heat to pre-heat green bricks. This means less heat is lost, and firing is more efficient. Also, the structure of the kiln doesn't need to be heated up for each batch of bricks. Continuous kilns, such as a Hoffman kiln or a Bull's Trench, are usually only feasible for brickworks making 10,000 or more bricks per day. There is a lack of designs for smaller continuous kilns. However, anything brickmakers can do to use waste heat will cut costs. The Vertical Shaft Brick Kiln (VSBK) is a continuous kiln, originally of Chinese design, that is being promoted and slowly gaining acceptance in some countries in South and East Asia.

6 Green bricks should be dry going to the kiln

If green bricks still contain a lot water when they are placed in the kiln, then energy, and money, is wasted just to dry them. In hot, dry climates bricks should be slowly but completely dried before firing using energy from the sun.

> Example
> Señora Jara used to rush her freshly moulded bricks to be fired. The bricks weighed 3.60 kilograms going to the kiln, and 0.60 kilograms was water. It takes at least 2.59 MJ to raise each kilogram of water to boiling point and evaporate it. So, Senora Jara was using 15,540 MJ in each 10,000 brick clamp just to dry her bricks. This used 0.62 tonnes of coal and cost her more than $248 per clamp.

7 Fuel should be dry

As with the bricks themselves, if the fuel contains water, then energy is wasted to evaporate it. If using fuelwood, it should be dry and seasoned. Large, dense, slow burning logs are generally better than the same mass of small, green twigs.

8 Good kiln control saves energy and money

Kiln temperature should rise quite slowly and constantly, otherwise heat is wasted. And, if the temperature rises too fast, bricks can be damaged. The temperature shouldn't be allowed to fall until firing is complete. As a rough guide, a 40,000 brick kiln fired externally might be slowly heated over a period of 2 or 3 days until no more steam comes from the top. It should then be fired for 4 to 6 days until the bricks at the top are getting red hot. The kiln is then sealed at the top, and the fires maintained for about a day. After this 'soaking' stage, the kiln is completely sealed and allowed to cool. It may take a week or two before it's cool enough to open. Smaller kilns will burn more quickly, larger ones more slowly.

The flow of air through a kiln should be controlled - too much will cool the bricks and waste energy, too little and the fuel will not burn completely. The major loss from most kilns is due to too much cold air being drawn in. Using a permanently set hearth, or fire grate, and dampers, allowing better control of the firing process, could offer substantial savings. Protecting the fires from cooling winds by using wind breaks will also promote economy and help the kiln burn evenly throughout.

9 Record keeping is important

Unless it is known how much fuel, or more precisely energy, a particular kiln used, it will be impossible to know when improvements have been made: has less fuel been used? Were costs reduced? Practical Action has developed a system for kiln monitoring which means not only can one firing be compared with another, but the efficiencies of different processes around the world can be compared directly.

10 Replacing primary fuel with free or cheap waste reduces costs

If free, 'waste' materials can be used instead of some part of the expensive primary fuel, this saves money. Agricultural residues, which might be used to partially replace fuel, include rice husk, sawdust, straw, maize cobs, and animal dung. Industrial wastes such as coal dust, boiler waste or pulverised fly ash often retain a high calorific value and are cheap. Brickmakers should check what is available.

Summary

For small-scale brickmakers perhaps the easiest step to improve efficiency and save money is to make sure bricks are dry going to the kiln. Then it's possible, without too great an investment, to work on kiln control: following a good firing regime and controlling air flow. Increasing insulation, particularly of clamps which can be scoved with a thicker layer of mud, offers a potential saving without a big cash outlay. Substitution of wastes for part of the primary fuel, and incorporating some fine fuel into the body of bricks can be done on a small, experimental scale to minimise the cost of any failures. Keeping good records costs only a little time and effort.

A radical way to save all the energy used to fire bricks is not to fire them at all! Where fuel is very scarce or very expensive, unfired, sun-baked bricks can be used for many applications provided good architectural design protects them from rain, floods, ground and splash water. The same is true of rammed earth construction. Stabilising soil with cement, lime or bitumen is another option.

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