ALAN MAHMOOD MAJEED

# BRICKS

**Contents** **Page**

## Introduction

The hanging gardens of Babylon, one of the seven wonders of the world; the great wall of China, the largest man- made object on the planet; the Hagia Sophia, one of the most beautiful churches ever built; and many more- all these have one thing in common: they were built out of brick. Brick is the simplest and the most versatile of materials, its story starts at the very beginning of the history of civilization. The mud brick was invented between ١٠,٠٠٠ and ٨٠٠٠ BC; the moulded brick was developed later, in Mesopotamia about ٥٠٠٠ BC; but the most significant landmark was the invention of the fired brick in about ٣٥٠٠ BC. Firing the brick gave it the resilience of stone but with the added advantages that it could be more easily shaped and provide potentially endless exact repetitions of decorative patterns. The ١٨th century saw the beginning of the Industrial Revolution in England, methods of making bricks and techniques were developed that allowed them to be manufactured in vast numbers and transported across long distances. At present new techniques in the manufacture and structural use of brick promise a bright future. The aim of this project is to examine the impact that the use of bricks has on the environment and how sustainable their use could be.

Photo. ١. The Great Wall of China (*Google images*).

**A- How much brick is used in construction? Is this use is increasing or decreasing?**

Bricks are mainly used for construction purposes like buildings and pavements, they are also used in the metallurgy and glass industries for lining furnaces. They have various uses, especially refractory bricks such as silica, magnesia, chamotte and neutral (chromomagnesite) refractory bricks. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. There is a large refractory brick industry, especially in the United Kingdom, Japan and the United states.

In the United Kingdom, bricks have been used in construction for centuries. Until recently, almost all houses were built almost entirely from bricks. Although many houses in the UK are now built using a mixture of concrete blocks and other materials, many houses are skinned with a layer of bricks on the outside for aesthetic appeal.

The output of bricks has changed enormously between ١٩٤٨ and today. For example, the total output of bricks in ١٩٩٠ was about ٤ billion, where as in ١٩٦٥, the output was ٨ billion (University college London, ٢٠٠٢). The main use for bricks is house-building has dropped dramatically since the ١٩٦٠s. This is probably because of the substitution of other materials (e.g. cement-based blocks), and because building regulations dictate higher standards of thermal insulation than before, lightweight blocks are made from a variety of other materials and they have a high porosity, which give better insulation, and they are also therefore lighter, so they can be manufactured into much bigger volumes than a standard brick. Walls made of these bigger blocks are cheaper and quicker to build than the ones made with conventional bricks. The types of movement experienced by various building materials are indicated in table (١).

Table. ١.
Types of Movement of Building Materials
(*Brick Industry association*)

| Building Material | Thermal | Reversible Moisture | Irreversible Moisture | Elastic Defor-mation | Creep |
|---|---|---|---|---|---|
| Brick Masonry | X | -- | X | X | X |
| Concrete Masonry | X | X | -- | X | X |
| Concrete | X | X | -- | X | X |
| Steel | X | -- | -- | X | -- |
| Wood | X | X | -- | X | X |

**B- How are bricks produced and what impact does their production have?**

In the past, bricks came in many different shapes and sizes, but today's modern bricks tend to be a standard size of around ٨" x ٤" x ٢". They demonstrate a wide variety of textures, colours and finishes from yellows, reds and purples, to smooth, rough and rustic. These are due to the mineral variations found in the clay, and the method of manufacturing.
Bricks are traditionally manufactured by mixing clay with enough water to form a mud that is then poured into a mould of the desired shape and size, and hardened by being fired in a tunnel kiln in which fire remains stationary and bricks are moved on kiln cars through a tunnel divided preheat, firing and cooling zones, or they can be hardened by sun light. Adobe bricks, very fashionable in parts of the USA, are still made in this way with a mixture of clay and sand (and sometimes manure and straw) being poured into a form, and then removed and dried in stacks outside in the sun.

Modern methods of brick manufacture are highly mechanised and automated procedures whereby clay is extruded in a continuous column, wire cut into bricks, and hydraulically pressed to ensure resistance to weathering. The bricks are then dried and slow fired at around ١٠٠٠ - ١٢٠٠° C.

Phases of Manufacturing:

The manufacturing process has six general phases:

١. Mining and storage of raw materials.
٢. Preparing raw materials.
٣. Forming the brick.
٤. Drying.
٥. Firing and cooling.
٦. De-hacking and storing finished products. (*See Figure* ١).

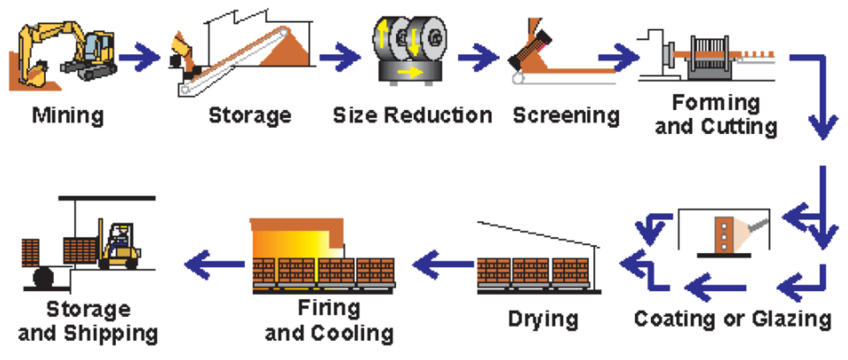


Figure ١
Diagrammatic Representation of Manufacturing Process
(*The Brick industry association*)

The production of bricks has both positive and negative effects. On the one hand, positive effects include employment opportunities, income generation and provision of building materials. On the other hand, negative effects include air pollution, land degradation and water pollution, especially in developing countries. It is one of the large sources of greenhouse gas emissions, unless interventions that will induce change are implemented, greenhouse gas (GHG) emissions will continue to grow unabated accompanied with deteriorating air quality.

Brick production can alter the landscape in ways that are harmful to the environment and may hamper future business plans. Production can deplete local sources of fuel, eventually raising the cost of labour for acquiring fuel. It can also create clay pits or “borrow” areas, which, if improperly managed, can become safety hazards, they may also accumulate rain water and become habitat for mosquitoes (See Photo.٢) These effects, with associated soil erosion, may make land unusable for farming. Therefore, despite the importance of brick making, the need for environmental conservation must also be taken into account.

Photo. ٢. Bradley Fen clay pit in Lower Oxford Clay (*Ordnance Survey*)

### C- How much energy is used in the production of bricks?

According to the Brick Industry Association, "The actual embodied energy of brick (the energy required to mine, manufacture and transport it), is approximately ٤٠٠٠ BTU’s per pound or ١٤٠٠٠ BTU’s per standard brick”. According to the AIA (American institute of architects), “the embodied energy of bricks is less than that of concrete, glass, steel, or aluminium. And it’s far below the embodied energy of EIFS and fibercement products."

The average direct energy consumption of the production process is to be found ranging between ١٨٤٠ and ٢٨٠٠ kJ/kg of fired brick (of which about ١٥٠ kJ/kg are electrical) to the process energy content of the product, or grey energy, energy contents due to transport and production of raw materials must be added in order to obtain the overall environmental impact. A good assumption is to calculate this additional energy content with about ٨٠٠ to ١٢٥٠ kJ/kg of fired brick, (American Brick Institute Clemson, ٢٠٠٤). (See table ٢)

Table. ٢

Energy content values for selected construction materials

(*American Brick Institute Clemson,* ٢٠٠٤)

| | Bulk density kg/m3 | Energy content MJ/m3 |
|---|---|---|
| Brick fired with fossil fuels | 700 | 2,524.20 |
| Reinforced concrete | 2,400 | 5,264,90 |
| EPS | 20 | 1,928.00 |
| Rockwool | 80 | 1,399,40 |

**Selected Mitigation Strategies to reduce fuel consumption:**

- Use alternative fuel types. Organic wastes such as rice husks or sugar bagasse can supplement scarce fuel sources, such as wood, without sacrificing efficiency.

- Raise kiln temperature using improved firing techniques. Adding combustible material around the bricks or between clamps can increase temperatures and lower traditional fuel needs.

- Maintain kiln structure and repair cracks or leaks. Even small leaks can substantially increase fuel costs over time. Monitor structure and machinery to identify potential leaks.

- If traditional brick-making technology is used (brick clamps), ensure adequate insulation of the clamp and orient it at a ٩٠° angle to prevailing wind direction to reduce underfiring or overfiring of bricks.

- Increase efficiency and reduce emissions by using kiln structures that require less fuel. Ventilated-shaft brick kilns (VSBKs) or bull trench kilns (BTKs) are effective in reducing smoke and lowering the amount of fuel required for firing.

It is comforting to discover that brick remains a leading building material that can be trusted to deliver high performance, low maintenance, long life and a comparatively small footprint on the world, which can be achieved by these mitigation strategies.

The European brick and tile industry is concerned about the energy used by the bricks production. Much effort has already been made to decrease its energy consumption (see table. ٣. below) and levels of $CO_٢$ emissions.

Table.٣. Reduction in the energy consumed by the brick and tile industry
*(TBE-Europe ٢٠٠٥)*

Specific Energy Consumption (GJ/tonne) – Brick & Roof-tile Industry

| | 1980 | 1985 | 1990 | 1995 | 2001 | Reduction %[6)] |
|---|---|---|---|---|---|---|
| AUSTRIA | 2.38 | 2.09 | 1.71 | 1.72 | 1.65* | 28 |
| BELGIUM | 3.30[2)] | 2.73[2)] | 2.16[2)] | 2.37[3)] | 2.23[3)] ** | 32 |
| GERMANY | 2.43 | 2.31 | 1.93 | 1.63 | | 33 |
| DENMARK | 2.73 | - [1)] | 2.41 | 2.67 | | 2 |
| SPAIN | 2.38 | 2.29 | 2.24 | 2.18 | | 8 |
| FRANCE | 2.87 | 2.62 | 2.76 | 2.61 | | 9 |
| ITALY | 2.8 | 2.6 | 2.1 | 1.9 | 1.9 | 32 |
| THE NETHERLANDS | 3.63 | 2.93 | 2.86 | 2.7 | | 26 |
| UNITED KINGDOM | 1.1[4)]<br>3.58[5)] | 1.01[4)]<br>3.26[5)] | 0.84[4)]<br>2.97[5)] | 0.83[4)]<br>2.80[5)] | 2.42[4)]<br>1.4[5)] | 25[4)]<br>22[5)] |
| SWITZERLAND | - [1)] | 2.55 | 2.62 | 2.53 | 2.32 | 1 |

* 2000

** 2002

1) not available

2) only bricks - data based on NIS

3) clay bricks and roof tiles - based on data provided by the federation

4) UK Fletton & 5) UK Non-Fletton / data for 1980 not available - data shown for 1984. The Fletton Industry cannot be compared to the previous figures. There have been large production changes to the output types at the 3 remaining fletton sites.

6) 1995/1980 but 1995/1985 when the 1980 consumption data are not available - for Belgium ratio 1980/1990

### D- How much CO٢ is released as a by-product?

Apparently the world's brick making industry accounts for about ٢% of global CO٢ emissions, about the same as the airline industry. This is according to a story in an article in (*Wellington's Dominion Post*).

To assess the amount of CO٢ released by the production of bricks, we should measure the Embodied Carbon Dioxide, which is the amount of CO٢ given off when manufacturing unit quantity of the material ( usually ١ Kg or ١ tonne ).

Units: Kg of CO٢/Kg of bricks

Kg of CO٢/tonne of bricks

There will be a link between embodied energy and embodied carbon dioxide, as CO٢ is produced and emitted to the air when energy is consumed. Materials with high embodied energy values will also tend to have high values of embodied CO٢.

By measuring the amount of energy it takes to manufacture and supply bricks to their point of use. Bricks have been labelled as having high embodied energy due to their process of manufacture. However, it is necessary to take into account a material's life cycle performance, as well as the amount of energy consumed in the manufacturing process.

Research recently undertaken demonstrates that the proportion of embodied energy of clay bricks for the modern semi-detached home is equal to just ١.٨٧% of the overall heating requirement for the home over its ١٥٠ year life, if we spread the CO٢ emissions from the brick in a square metre of brickwork over a life of ١٢٠ years it equates to ٠.٠٠٠٢٣٢ tonnes of CO٢ /sq metre/per annum. This carbon isn't "locked up" to be released at the end of life, it has already been expended and the longer the building exists, the better the value. (Brick Development association, ٢٠٠٩)

(See fig.٢) below, the bulk of the additional embodied CO٢ is used in brickworks comparing with the other operations in a building project (*The Empty Homes Agency Ltd*).

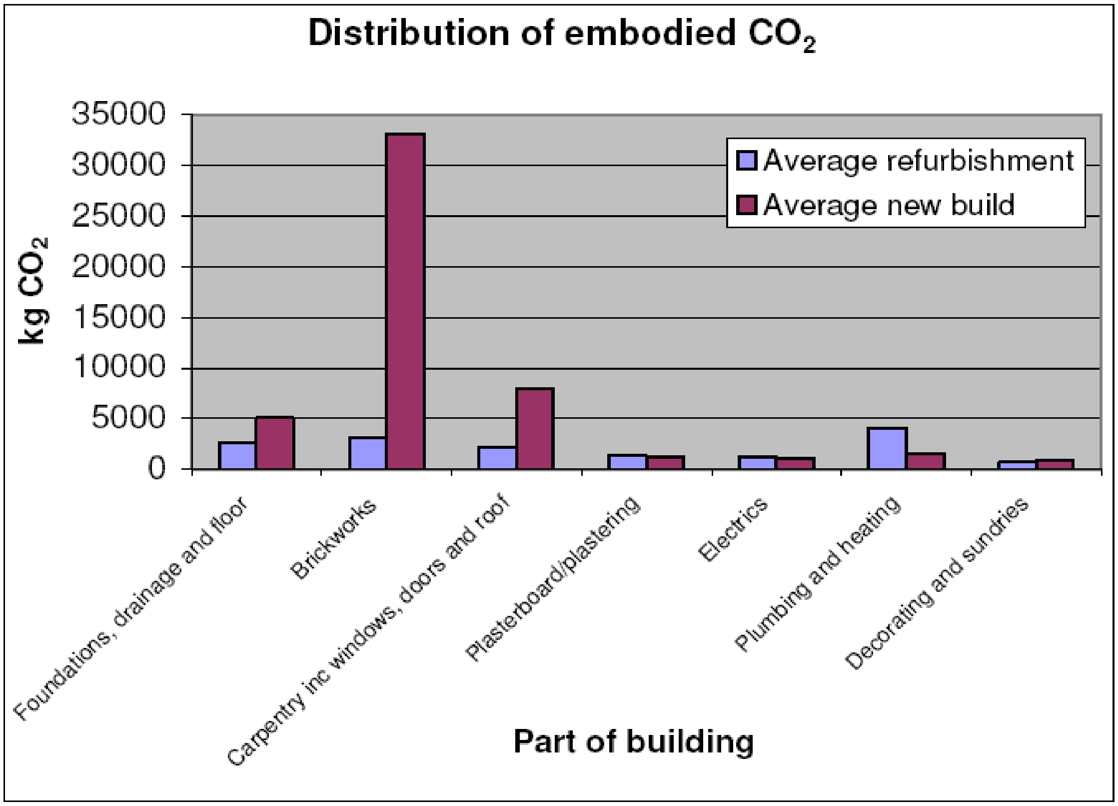


Figure ٢

Different operations embodied CO٢ (*The Empty Homes Agency Ltd*).

### E- Does the production process use any waste products from other industries?

Materials from Alternative, Recycled and Secondary Sources (MARSS) are increasingly important in the manufacture of clay bricks - the current level of recycled material content in brick is ١٢.٠٨%, an improvement on ٢٠٠٥ (*CERAM* ٢٠٠٧).

Nonhazardous waste products from other industries are sometimes used. Examples include using bottom- and fly-ash from coal-fired generators, using other ceramic materials as grog, using lubricants derived from processing organic materials in the forming of brick, and using wood dust as a burnout material.

The successful introduction of a selective blend of solid by-product wastes into the feedstock replacing quarried raw materials has an immediate effect (See fig.٣).The lesser the use of primary raw materials the lesser the environmental footprint of a production process.
Also, very little clay is wasted during manufacture. Unfired waste clay is reused in the manufacturing process.

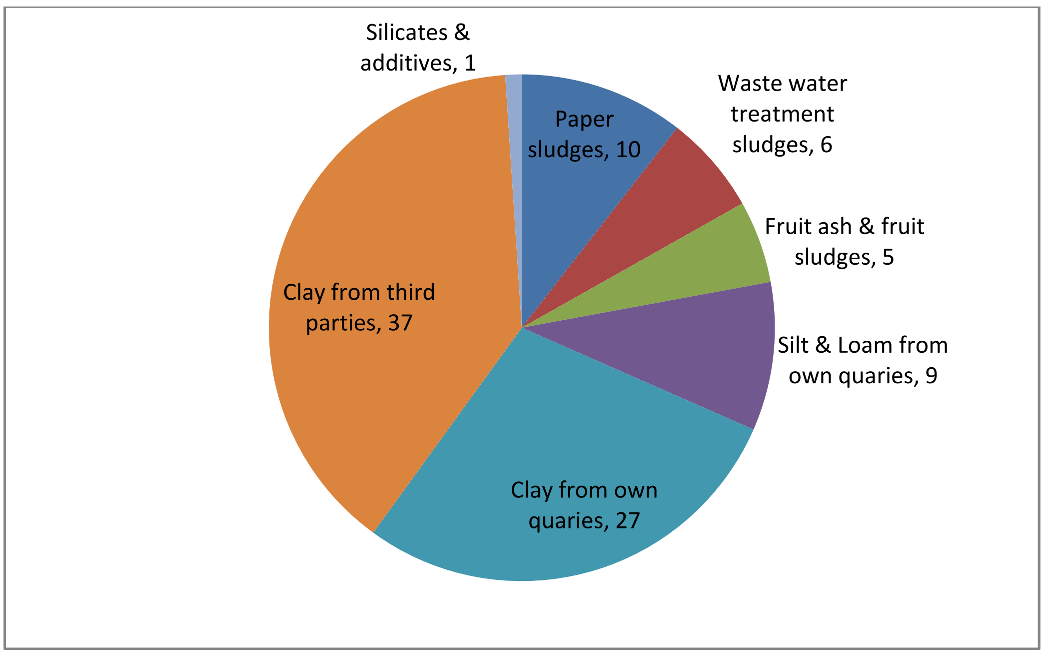


Figure. ٣

Material consumption in % of total material input flow (*New building products,* ٢٠٠٣)

### F- What other environmentally damaging emissions / pollution arise from the production of bricks?

Emissions from brick manufacturing facilities include particulate matter (PM), PM less than or equal to ١٠ microns in aerodynamic diameter (PM-١٠), PM less than or equal to ٢.٥ microns in aerodynamic diameter (PM-٢.٥) sulfur dioxide (SO٢), sulfur trioxide (SO٣), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO٢), metals, total organic compounds (TOC) (including methane, ethane, volatile organic compounds [VOC], and some hazardous air pollutants [HAP]), hydrochloric acid (HCl), and fluoride compounds. Factors that may affect emissions include raw material composition and moisture content, kiln fuel type, kiln operating parameters, and plant design.

The pollutants emitted from the manufacture of other structural clay products are expected to be similar to the pollutants emitted from brick manufacturing, the primary sources of PM, PM-١٠, and PM-٢.٥ emissions are the raw material grinding and screening operations and the kilns. Other sources of PM emissions include sawdust dryers used by plants with sawdust-fired kilns, coal crushing systems used by plants with coal-fired kilns, and fugitive dust sources such as paved roads, unpaved roads, and storage piles.

Combustion products, including SO٢, NOx, CO, and CO٢, are emitted from fuel combustion in brick kilns and some brick dryers (See Table.٤). Brick dryers that are heated with waste heat from the kiln cooling zone are not usually a source of combustion products because kilns are designed to prevent combustion gases from entering the cooling zone. Some brick dryers have supplemental gas burners that produce small amounts of NOx, CO, and CO٢ emissions. These emissions are sensitive to the condition of the burners.

Table. ٤

Total annual emissions from U.S. clay brick manufacturing

(*Freight Pipeline Company ,FPC*)

| Air pollutant | CO | NOX | SOX | VOC | PM[1] | TAP |
|---|---|---|---|---|---|---|
| Annual amount (tons/yr) | 7769 | 2616 | 2530 | 646 | 4785 | 18346 |

١. *Total particulate matters (PMs) up to ١٠ microns in diameter.*

A variety of control systems may be used to reduce PM emissions from brick manufacturing operations. Grinding and screening operations are sometimes controlled by fabric filtration systems, although many facilities process raw material with relatively high moisture content (greater than ١٠ percent) and do not use add-on control systems. Most tunnel kilns are not equipped with control devices, although fabric filters or wet scrubbers are sometimes used for PM removal. Particulate matter emissions from fugitive sources such as paved roads, unpaved roads, and storage piles can be controlled using wet suppression techniques.

Vertical shaft brick kilns allow increased production rates and significantly decreased emissions through improved combustion air flow efficiency. Several other kiln designs have also proven to be relatively low-cost and much more efficient than traditional ovens or kilns (*The Clay Brick Industry*).

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. Manufacturers can profit from CP through more efficient use of inputs and machinery, higher-quality goods that command higher prices, and reduced waste disposal costs.

**G- How durable are bricks? Would there be any advantages to making them more durable or easier to obtain?**

Brickwork has a long record as one of the most durable and versatile building materials. However, as with all such materials, there are a few essential considerations to ensure satisfactory performance:

- Correct selection of the brick for the site conditions.
- Proper mortar mixing.
- Suitable design and detailing.
- Correct installation of fittings and connections to adjacent building materials and components.

Brickwork is subject to natural weathering such as rain, sun, wind and wind-borne sea spray. The pollutants that may attack brickwork include salts produced by soil fertilisers in former rural areas, dredged landfills in canal estates, pollution from nearby industrial estates, vehicle exhaust emissions, especially at busy road junctions, and even splashes from salt water swimming pools. Probably the most severe effect on durability is attack by sulphate salts. Sulphate and chloride salts are soluble in water, which is how they move into and through brickwork. These salts will attack bricks and mortar.

The durability of brick depends upon achieving incipient fusion and partial vitrification during firing. Because compressive strength and absorption values are also related to the firing temperatures, these properties, together with saturation coefficient, are currently taken as predictors of durability in brick specifications (*Brick Industry Association,* ٢٠٠٨). However, because of differences in raw materials and manufacturing methods, a single set of values of compressive strength and absorption will not reliably indicate the degree of firing.

Advantages of making bricks more durable:

- Fired clay products can have high compressive strengths, even when wet' making them resistant to impact and abrasion. The excellent condition of many ancient brick constructions clearly demonstrates the durability of fired clay products.
- The porosity of fired clay permits moisture movement, without significant dimensional changes. Brick and tile constructions can "breathe".
- Fired clay products provide excellent fire-resistance.
- Bricks and tiles are weather resistant and can remain without any surface protection, thus saving costs.

**H- Can bricks be easily re-used or recycled? Is there a need to improve the technology for recycling bricks?**

Recycling and salvaging construction materials is great for the environment. It's also great for business. Clay bricks themselves can be recycled without any problems if they have not been contaminated during their use phase with any substances or products that will make it difficult or impossible to recycle them (see photo.٣). The substances that might cause problems in recycling bricks are mortars, glues, wire and plumbing, paint and similar substances. It is the obligation of the planner to design for future recyclability by considering how the building can be recycled and possibly disassembled. Bricks can be re-used, providing the mortar can be removed. Modern Portland cement mortar can be quite difficult to remove, because of its high strength. The lime mortar used in Victorian times is very much easier to remove.

Photo. ٣
Reusing old bricks in new buildings (*Masonry Magazine,* ٢٠٠٧)

Midland Brick have developed an innovative, multi-award winning recycling program where old, broken and unwanted clay bricks, pavers and roof tiles are crushed back to their original state and reused in the manufacture of new internal brick products. All waste received on site is dealt with using sorting grabs, trommel screen, picking line and crusher to extract all municipal waste. ( *see photo ٤. Bricks recycling plant* ).

By recycling this waste, Midland Brick minimises mining and diverts waste materials from landfill - benefits unequalled by any other building material. The strength, quality and technical specifications of new internal brick products that contain recycled waste are not affected in any way. Since the recycling program began in July ٢٠٠٦, over ٤١,٠٠٠ tonnes of waste has been recycled. This is equivalent to over ١٤.٦ million bricks, or enough to build over ٦٦٦ average double brick homes (*Midland bricks Ltd,* ٢٠٠٩).


Photo. ٤
Bricks recycling plant (*HR skip hire*).

There is the need for more of these recycling programs to be established in the UK and elsewhere to reduce the amount of used bricks from demolished buildings being dumped in landfills which is becoming an increasing global problem as the spaces available for landfills will run out eventually. Overall, bricks are a good example of a sustainable building practice and are currently gaining in popularity around the world.

**I- What might be the effects of future developments in construction, changes to building regulations, development of intelligent buildings, new methods of construction, etc?**

The BRE's latest Green Guide to Specification has assigned the highest possible accreditation (A+) to every external wall it rated that contained brickwork, ( *Brick Development association,* ٢٠٠٨). It states that the choice of external wall specification is probably subject to the widest range of practical, economic and visual considerations compared to other building elements and can account for around ٣٠% of building costs. The guide provides designers with a user-friendly, yet authoritative guide to making the best environmental choices for materials and components. It is the industry bible for green ratings.

As the BRE's Green Guide makes clear, sustainability is not just about the use of carbon-free materials. Nor is it just about the embodied energy accrued in its production and delivery from 'cradle to gate'. It is about the total energy consumption of a product – including that used to maintain it, once it's part of a building, and the fate of 'end-of-life' material.

An investigation by the Royal Institute of Chartered Surveyors (RICS) found that, against a line-up of popular finishes for the external skin, installed brickwork beat just about all of them on price. What the RICS investigation showed is that you can have such qualities, without paying over-the-top prices (*RICS Website*). The study compared the installed cost per square meter for brickwork against a string of rival external finishes. These included simple fibre cement sheets, different types of rendered block work, timber weatherboard, PVC cladding, plain tile cladding, ashlar stonework, and, at the top end of the price range, curtain walling and patent glazing.

Some of the highlights were:

- Facing brick came in at £٥٩ m٢ (less than some sheeting, pebbledash and proprietary render systems)
- Two thirds the price of timber weatherboarding.
- Barely one third the price of ashlar stonework.
- Curtain walling is nearly eight times more expensive, patent glazing nearly nine times.

According to the (RICS), the materials that came in for less than brickwork included options with a lower life expectancy or high life cycle costs, such as single fibre cement sheeting and painted render. In its conclusion, the (RICS) notes: 'Brick is a competitive option for the external skin. Most of the options that are less expensive in the study fall within the range of available facing bricks'.

Brick offers a sense of stability. With our ever changing weather patterns bringing such weather extremes as floods and high temperatures brick is much more robust than many man-made materials and won't rot, rust, erode or decay. As we are increasingly affected by global warming, it is becoming more important to consider using materials that offer high thermal mass performance – clay brick is one such material. Thermal mass is the ability to store heat – bricks absorb heat throughout the day slowly releasing it at night, ensuring internal temperatures are consistent throughout the day and night. The result is comfortable and healthy living and working environments in which to enjoy stable temperatures throughout the year (see figure ٤).

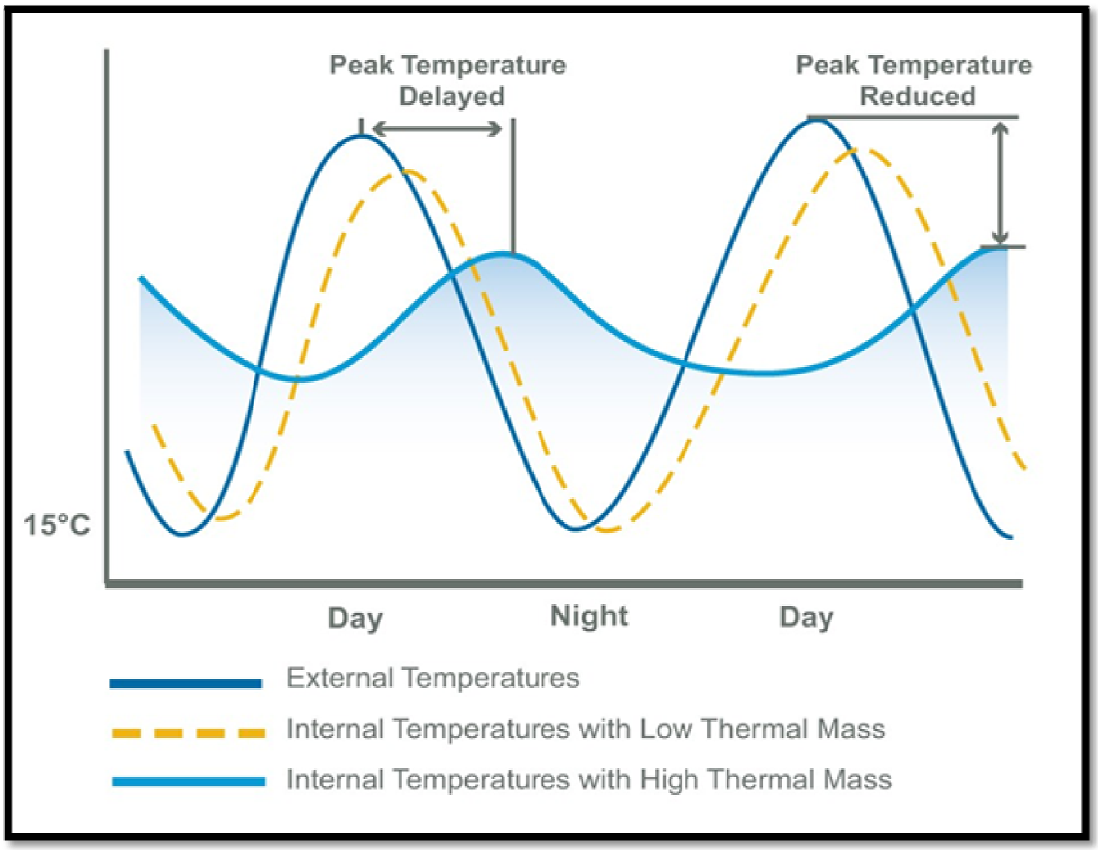


Figure. ٤

Stability in internal temperatures during day and night

(*Brick development association,* ٢٠٠٨)

**J- Current world oil consumption is running at over ٨٠ million barrels per day. How much of this does production of bricks consume?**

Traditional brick production requires a great deal of fuel during firing. Inefficient production technologies and techniques and excessive fuel consumption are typical. Natural gas is the most frequently used fuel for kiln firing, demand for both oil and natural gas continues to rise each year, world oil supply is likely to decline in the near future. With demand increasing and supply decreasing, there is certain to be a significant gap in the not too distant future (The oil drum magazine). Natural gas is similar. Like oil, we started with a finite quantity of it, and it is now depleting, it is likely to decline in the next few years, because most of the larger, more productive sites have already been tapped. New natural gas wells are getting smaller and smaller, so that more and more new wells need to come on line each year, just to stay even.

Some brick manufacturers are beginning to utilize readily available alternative solid fuels like coal or sawdust or renewable fuels such as biogas and liquefied rendering fat. The biogas is generated in an own plant based upon a process patented internationally by the brickyard itself. Rendering fat is supplied from rendering plants. Renewable fuels have the main advantage over fossil fuels that the resulting flue gases feature a lower content of contaminants such allowing to heat up the brick dryer directly by recycling the flue gases instead of having to have a separate source of heat to run the dryer. The achieved total heat requirement reduction alone by this measure is about ٣٠% of the former total heat requirement, (Ziegelei Gasser, ٢٠٠٤ ), see table(٥).

These alternative solid fuel sources can potentially shield brick manufacturers from the price volatility of the natural gas market. As the interest in alternative fuels and their economic value continues to rise, it will become increasingly necessary for kiln operations to be tested for quality and emissions.

Table. ٥

Energy content fossil fuel fired brick / renewable fuels fired brick

(*Ziegelei Gasser,* ٢٠٠٤),

| | Bulk density kg/m3 | Energy content MJ/m3 |
|---|---|---|
| Brick fired with fossil fuels | 700 | 2,524.20 |
| Brick fired with renewable fuels | 700 | 910 |

### K- Are bricks renewable or not?

Renewability assessment must involve all the materials that used in the production of bricks rather than just considering bricks on their own, the main resources are:

- Clay- renewable material with plenty of it available everywhere.
- Water-renewable to a certain extent depending on the amount used and its availability locally.
- Fuel- fossil fuels are not renewable as there is only limited amount of them left on the planet and they will run out eventually.

The latest annual figures available from BP's authoritative show that energy use grew ٢.٤% from ٢٠٠٦ to ٢٠٠٧ (*Statistical Review of World Energy* ٢٠٠٨). If we use this number as escalation against ٢٠٠ years at current usage, we actually only have ٧٥ years of fossil fuels left. Allow a more aggressive growth rate of ٥% to factor in industrialisation of currently less developed countries, and fossil fuels will be gone in ٥٠ years, (See figure ٥).

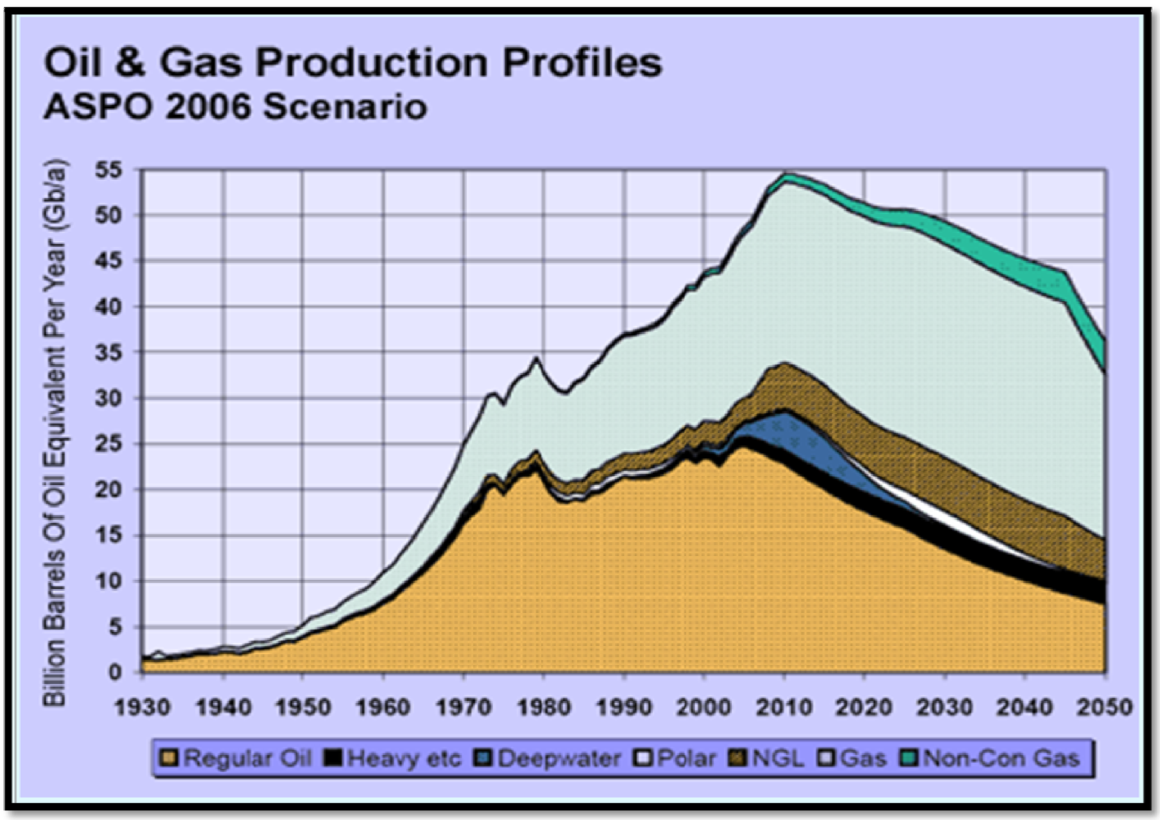


Figure. ٥

The depletion of Fossil fuels in ٥٠ years (*Statistical Review of World Energy* ٢٠٠٨)

**L- In terms of natural reserves of Bricks, are bricks practically inexhaustible or are reserves limited?**

Bricks are usually and generally understood as a sustainable product. Brick manufacturing is one of the most efficient uses of materials to produce a product. Brick plants are typically located close to raw material sources. Processed clay and shale removed in the forming process before firing are returned to the production stream. Brick not meeting standards after firing are culled from the process and ground to be used as grog in manufacturing brick or crushed to be used as landscaping material. There is virtually no waste of raw materials in manufacturing brick.

The primary ingredient, clay, has been termed an "abundant resource"(*American Institute of Architects, ٢٠٠٦)*, confirming that depletion of clay is not a concern. The brick industry's goal is to reduce resources used in the manufacturing process. Although water is used in brick manufacturing, it is not chemically altered but is evaporated into the atmosphere, new techniques been used to deal with this, by using storage tanks to recirculate and reuse water, potable water demand can be cut dramatically. Brick manufacturers are continuously looking for ways to minimize use of water.( Photo.٥) shows one plant using a storage tank to hold recirculated water for reuse in brick production, water is cleaned, cooled and moved to a holding tank for reuse.

Photo. ٥
Storage tank captures used water from manufacturing process,
(*The Brick industry association, ٢٠٠٦*)

## Conclusion

The history of the brick industry is a good example of the benefits of mass production. Today, much of the difficult, manual (hand) labour is performed by high-tech machinery and computer controlled robots. Laboratories ensure consistent clay mixtures. Temperature and atmospheric controlled kilns produce uniform, high quality bricks in hundreds of varieties, shapes, and sizes.

By decreasing the environmental impacts of the manufacturing of bricks by substitution of traditional raw materials with selected waste materials and of fossil fuels with renewable fuels, bricks will be a good example for both renewability and sustainability. Using a sustainable product for building is a contribution to greatly reduce the environmental footprint of one of the largest industries.

Bricks are attractive building materials with acceptable visual impact comparing to other materials and relatively inexpensive products with good mechanical properties. The natural resource (clay) is plentiful and readily available. These are necessary qualities of any good building material, nevertheless, bricks are essentially just burnt clay, and they have been around for thousands of years. With many elements of past brick buildings still standing today (see photo. ٦), brick is one of the only truly tried and tested materials known to man. Bricks can be regarded as an environmentally beneficial building material only over the whole life cycle. Its high durability fulfils the demand for environmental payback. However, since a long component lifetime also implies different uses, the design and construction should enable the potential for reuse.

Photo. ٦

Hagia Sophia- Istanbul, built in ٣٦٠ AD (*google images*).

## Bibliography


١. James W.P. Campbell. (٢٠٠٣) **Brick- A world History**. London, Thames & Hudson Ltd.
٢. Lindstorm, Martin. (٢٠٠٢) **Clicks, Bricks & Brands**. London, Kogan Page.
٣. Field, Robert. (١٩٩٦) **Geometric atterns from tiles & brickwork**. Tarquin.
٤. Cash, Terry. (١٩٨٨) **Bricks**. London, A.& C. Black
٥. Think Brick Australia (٢٠٠٧) **Bricks & Pavers** [internet], Australia. Available from: < http://www.thinkbrick.com.au/brick-data.cfm/> [Accessed ٢٧ February ٢٠١٠].
٦. University College London (٢٠٠٩) **Bricks** [internet], London, University College London. Available from: < http://www.es.ucl.ac.uk/schools/UCL/bricks.htm/> [Accessed ٠٢ March ٢٠١٠].
٧. The Brick Industry Association (٢٠٠٦) **Technical Notes on Brick Construction** [internet], Virginia, The Brick Industry Association. Available from: <http://www.gobrick.com/BIA/technotes/t٩.pdf/> [Accessed ١٠ March ٢٠١٠].
٨. The Schumacher Centre for Technology and Development(٢٠١٠) **Technical Information Online** [internet], Warwickshire, The Schumacher Centre for Technology and Development. Available from: <http://practicalaction.org/> [Accessed ١٢ March ٢٠١٠].
٩. Sustainable Build (٢٠١٠) **Brick Manufacture and Use in Construction** [internet], Sustainable Build. Available from: < http://www.sustainablebuild.co.uk/brick-manufacture-use-construction.html/> [Accessed ١٥ March ٢٠١٠].
١٠. Science Direct (٢٠١٠) **Study on fired bricks with replacing clay by fly ash in high volume ratio** [internet], Elsevier B.V. Available from: < http://www.sciencedirect.com/science/> [Accessed ١٨ March ٢٠١٠].
١١. American Society Of civil Engineers (٢٠٠٨) **Bricks Manufactured from Sludge** [internet], US, ASCE Publications. Available from: <http://cedb.asce.org/> [Accessed ٢٠ March ٢٠١٠].
١٢. Brick Development association (٢٠٠٩) **Sustainability** [internet], Brick Development association. Available from: < http://www.brick.org.uk/industry-sustainability.html> [Accessed ٢٨ March ٢٠١٠].
١٣. Oolitic Middle School (٢٠٠٧) **The Story Of Bricks** [internet], Indiana, Harley D. Brown. Available from: <http://www.nlcs.k١٢.in.us/oljrhi/brown/bricks/> [Accessed ٠١ April ٢٠١٠].
١٤. The Building and Social Housing Foundation (٢٠٠٨) **New Tricks with Old Bricks** [internet], London, The Building and Social Housing Foundation. Available from: <http://www.emptyhomes.com/documents/publications/reports/NewTricksWithOldBrickspdf/ > [Accessed ٠٣ April ٢٠١٠].
١٥. Masonry Magazine (٢٠٠٧)**Recycled Materials** [internet],Illinois, Brett Martin. Available from: < http://www.masonrymagazine.com/٤-٠٧/green.html/>. [Accessed ١٠ April ٢٠١٠].

١٦. The Oil drum (٢٠٠٧) **Alternative energy [** internet ], Prof. Goose. Available from: <http://anz.theoildrum.com/node/٢٤٢٣/>. [ Accessed ١٢ April ٢٠١٠ ].
١٧. The Clay Brick Industry (٢٠٠٨) **Improvement of Resource Efficiency and Environmental Performance** [internet], Burt Hamner. Available from: < http://www.green-trust.org/claybrick.htm/>. [Accessed ١٣ April ٢٠١٠].
١٨. Freight Pipeline Company (FPC) (٢٠٠٧) **Environmental Benefits of Greenest Brick** [ internet ], Henry Liu, Melissa Shinn and Carla Roberts. Available from: <http://www.greenestbrick.com/files/Greenest_Brick_Benefits.pdf/>. [ Accessed ١٥ April ٢٠١٠ ].
١٩. Handisyde, C.C.( Cecil Charles ). (١٩٨٢) **Hard landscape in brick**. London, Architectural Press.