The Clay Life Cycle

1 Quarrying and Reserves

The clay brick and tile industry is an extractive industry relying on natural resources for its raw materials. The process can be handled in a sustainable manner with restoration following extraction.

It is vital for the industry that there is long term mineral planning to ensure security of supply and thereby encourage investment.

1.1 Social Progress

The location of brickworks, tileworks and their quarries in rural and semi-rural areas has allowed the industry to provide long-term, stable employment to small neighbourhoods and communities. An established relationship between manufacturer and community can fulfil many of the sustainability criteria considered under social progress.

1.2 Environmental aspects

The end product and its characteristics are determined by the raw material. The extraction of clay is in most cases directly connected to the production process. Little waste occurs because extraction is only economical where the ratio of usable to unusable material is high. Extraction is not a continuous process so the immediate impact and rate of change is not significant. Compared to other industrial minerals, volumes and rates of extraction are very low, while numerous socially and environmentally beneficial uses are found for exhausted clay pits, e.g. nature reserves, recreational facilities.

Clay is usually extracted in close proximity to the works. The volume required can be accurately assessed so there is little risk of waste. Therefore prudent use of resources is ensured.

1.2.1. Extraction and restoration

The clay brick and tile industry produces a wide range of products from a diverse range of natural resources. In order to maintain and enhance the quality of life for future generations we will:

- Conserve natural resources as far as possible ensuring that only that which is necessary is used to meet the demand;
- Minimise environmental impact of mineral operations and transport;
- Minimise waste and encourage efficient use of materials;
- Enhance environmental quality around clay pits once extraction has ceased;
- Protect areas of designated landscape or nature conservation from mineral development.

The extraction of clay for construction products is a small percentage of the total mineral extraction, typically about 5%. If deposits lie deep, land usages rates are modest, whilst in delta areas extraction is managed with minimal disruption.

Clay brick and tile manufacturing plants are frequently situated alongside clay deposits or sand quarries thereby minimising the energy expended in transporting material to the factory. Clay brick and tile companies have adopted voluntary codes of practice covering all aspects of extraction and restoration. Such good practices cover site appearance, prevention of pollution, reduction of ecological impact, restoration and aftercare.

Although the extraction of clays and sands has an environmental impact, it also has potential benefits, such as the creation of nature reserves, amenity lakes and the formation of repositories for various forms of waste. This is particularly useful as the impervious nature of exhausted clay pits provides an acceptable means of waste disposal.

Gas produced from landfill can be used in nearby clay brick and tile production plants or elsewhere, thereby reducing the reliance on non-renewable energy sources. Restored land over exhausted clay pits can provide useful social amenities or be converted to agriculture or forestry use.

1.2.2 Resource management

It must be remembered that access to mineral resources can be blocked by other forms of development. It is in societies interest that the extraction of raw materials is combined with other forms of development. Extraction is largely regulated by the mineral planning system, therefore we have to pay due regard to:

- Overall need to incorporate economic, environmental and social considerations in the planning process,
- Knowledge of the mineral resource base,
- Adequacy and quality of mineral supply,
- Development of an integrated approach to managing conservation of resources,
- Incorporation of long-term planning strategies, including security of supply,
- Incorporation of land use and other sustainable objectives in the planning process,
- Incorporation of influence and feedback of mineral issues within all levels of administration.

The management of resources is fundamental to a manufacturing industry. However, this responsibility is also shared by Government. Our industry is prepared to invest if there is certainty about the raw material supply. Ideally the planning process should allow for the consideration of three levels of projection:

- long-term possibilities (25 years and over),
- medium-term probabilities (12 – 25 years),
- and short-term confirmed (1-12 years).

Therefore it is important that specific clay brick and tile issues are addressed at the European and national level in order to:

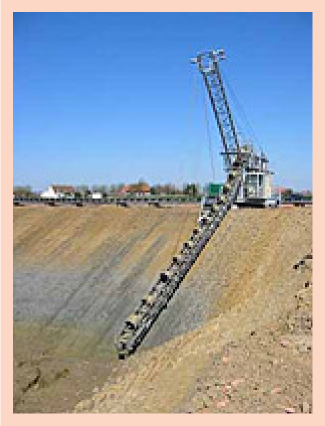
- Ensure that development plans take account of specific issues related to clay bricks and tiles,
- Ensure that development plan policies provide a sustainable long-medium-short term security of clay supply and are informed by dialogue between the relevant parties,
- Take account of geographical changes in the economic importance of clay resources, manufacturing centres and markets,

- Ensure a diverse raw material supply to provide a range of products that reflect design requirements,

- Take account of the transport of raw materials and products and the growth in the import/export of clay and other materials across administrative boundaries.

If these issues are faced and resolved by both manufacturers and regulators, then there will be a sound basis on which to justify investment in this industry – itself a fundamental requirement of sustainability and in the interest of those that need housing in the future.

1.3. Economic issues



Clay is one of the oldest building materials known to man and its extraction has been tailored to suit the prevailing demands.

Today, it is possible to produce both conventional and innovative products that will keep demand levels high.

The development of new manufacturing techniques maintains clay brick and tile as competitive building materials that have good quality, long life and minimal maintenance requirements.

2 Production Process

The manufacture of clay building products is constantly improving. The clay brick and tile industry is continually monitoring its energy usage which forms a significant part of total production costs. Much work has already been done to decrease energy consumption and consequently CO_2 emissions in line with government guidelines. Firing gives our products their exceptional performance, long life and durability and is an indispensable part of the production process.

Some products are designed to be energy efficient in use and there has been a significant increase in thermal performance qualities of products over the past few years. Our objective is to continue this trend in order to deliver efficient products that are manufactured with careful energy usage, controlled emissions and minimal waste.

2.1 Short description of the Production Process

After extraction from quarries, the clay raw material is laid out in order to obtain a homogeneous mixture.

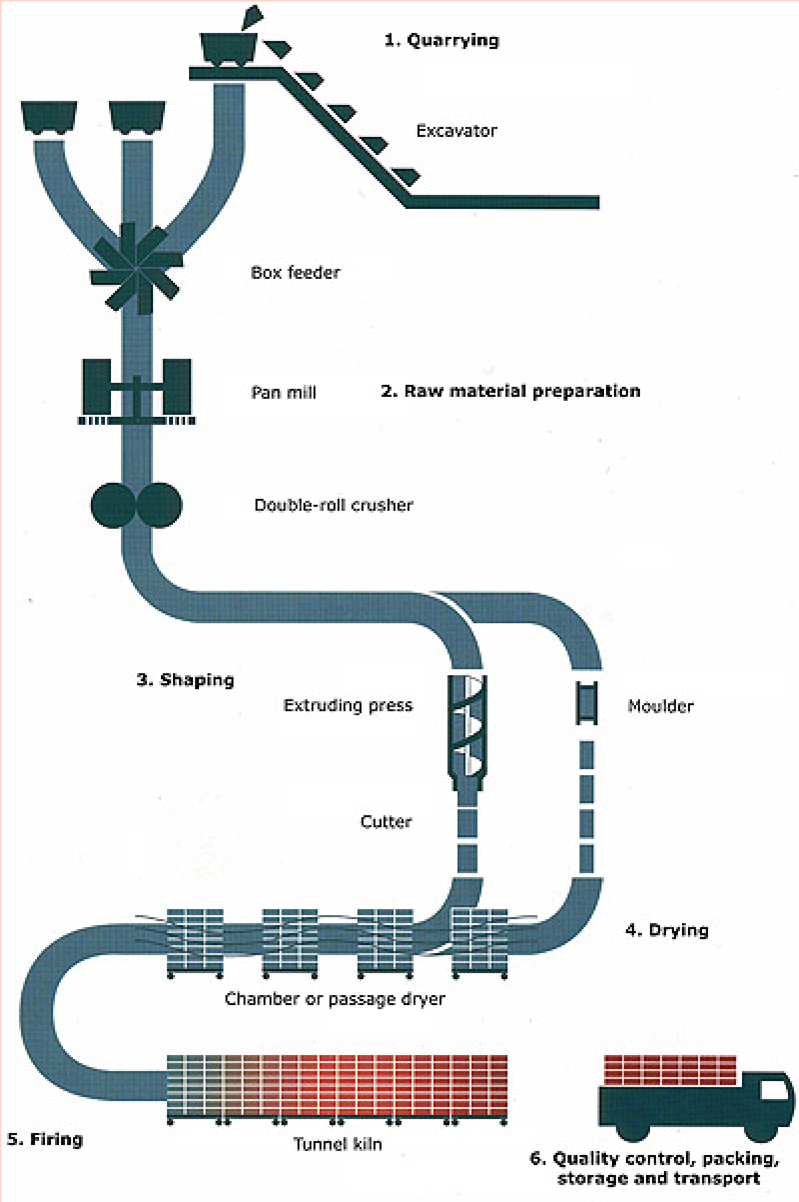
Several stages are involved in preparing the clay. It is stockpiled , then crushed to attain the required grain size and then stockpiled again for several days or even months.

Before processing, the moisture content is controlled and it may be necessary to add water to obtain the right consistency for forming. Materials such as sawdust or residue of paper industry can be added to increase the porosity of the final product.

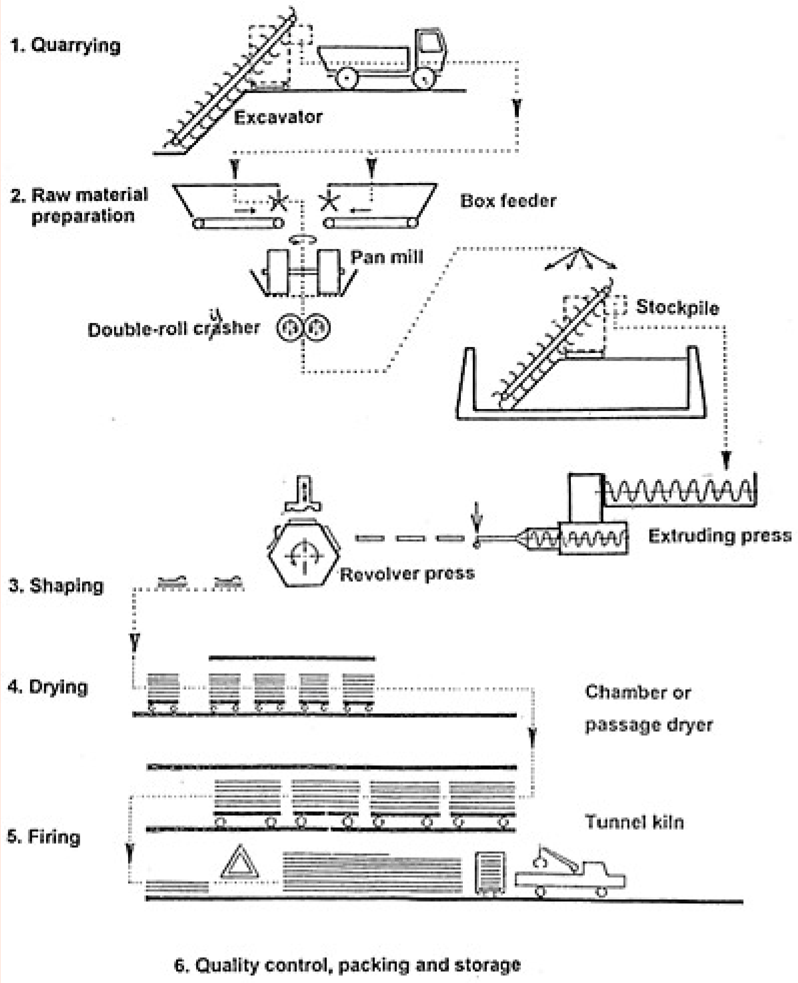
For bricks, the clay is extruded or moulded to obtain the shape required and then cut to size. In roof tilemaking, the clay can undergo a two-stage process, the second of which may occur after extrusion, depending on the roof tile being manufactured. For example, for interlocking tiles, the extruded clay is pressed between two moulds.

The formed clay is dried in order to reduce its moisture content and then loaded into kilns for firing. When this is completed and the products have cooled, they are packed ready for dispatch. Throughout all stages of production, the process is subject to rigourous quality control.

Example of Production of extruded bricks and handmade bricks



Example of production of pressed roofing tiles



2.2 Environmental Aspects

The clay building product industry has taken positive steps to deal with the inherent environmental aspects of the process. Constant improvement is made especially with regard to the following:

2.2.1 Energy consumption: close monitoring

The energy consumed during the manufacture of clay products is primarily that used in forming, drying and firing. Since energy costs are an important part of total production costs (up to 30%), the clay industry has always closely monitored its energy usage. Ecology and economy are often linked and the European brick and tile industry has not waited for statutory regulation before investing in better energy efficiency. Firing is responsible for the exceptionally long life of our products. Moreover, some products are designed to save energy when incorporated into buildings and the thermal performance of such products has increased significantly over the last few years.

There are 3 ways of managing energy consumption:

Choice of energy
Reduction of energy consumption
Use of renewable energy

Choice of energy

Natural gas, LPG and fuel oil are used for most drying and firing operations, but solids fuels and electricity are also sometimes used, as is gas from landfills. Natural gas is increasingly used in factories. This fossil energy produces the least carbon dioxide- CO_2 (57 kg CO_2 / GJ as opposed to fuel oil which produces 75 kg CO_2 / GJ).

Development of the Percentage of Various Fuels Used (Thermal Energy)
Clay Brick & Roof-tile Industry

	COAL					OIL					NATURAL GAS				
	1960	1975	1990	1995	2001	1960	1975	1990	1995	2001	1960	1975	1990	1995	2001
AUT			2	0	0*			20	19	15*			78	81	85*
BEL	83	4	10	4	2**	17	40	7	6	2**	0	56	83	90	96**
GER	77	5	3	3		20	76	17	15		3	19	80	82	
DEN	68	11	5	4		32	89	9	9		0	0	86	87	
FRA		4	15	0			56	9	5			40	76	95	
ITA			0	2	0*			49	19	10*			51	79	90*
NED	49	2	2	1		51	1	1	0		0	97	97	99	
ESP	30	10	0	0		50	65	71	67		20	25	29	33	
UK		50	11	4	3		14	4	2	1		36	85	94	96
HUN	94	60	26	15		6	8	0	0		0	32	74	85	
CH			1	0	0			63	51	47			36	49	53

* 2000
** 2002
Data listed in this table are based on information provided by the National federations and associations. (source : TBE)

Reduction of energy consumption

Throughout the industry, the widespread change to gaseous fuels and improvements in drying, kiln technology and control have resulted in a progressive reduction in energy use and a marked reduction in emissions.

The primary process improvements are:

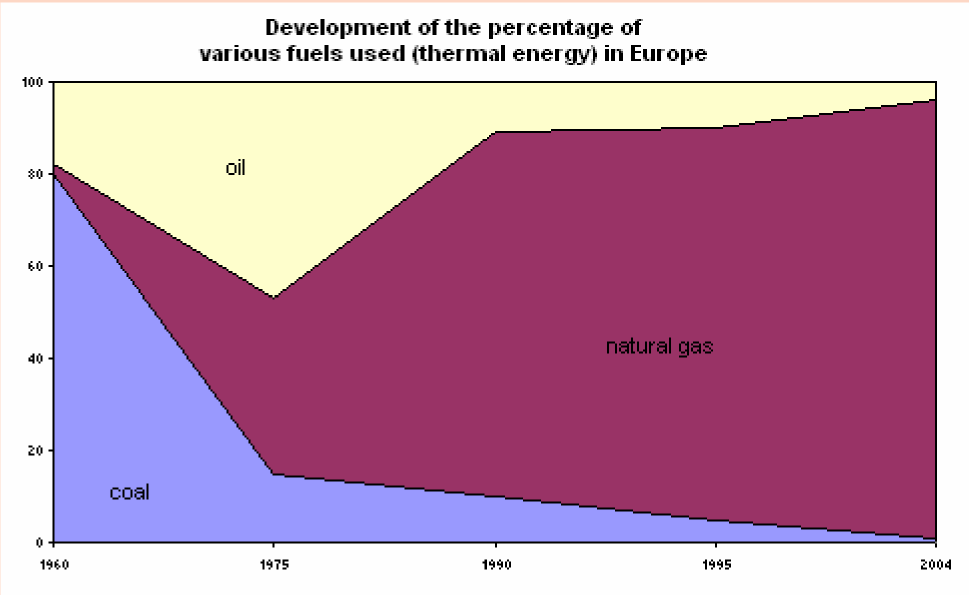
- improved design of dryers and kilns
- computer control of drying and firing regimes
- recovery of excess heat from kilns (mainly hot air from cooling zones of kilns ducted to dryers)
- product modifications

The EC/2003/87 Directive establishes a $C0_2$ emissions trading system. The European brick and tile industry is concerned by this Directive. Much effort has already been made to decrease its energy consumption (see table below) and levels of CO_2 emissions.

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) 3.58 5)	1.01 4) 3.26 5)	0.84 4) 2.97 5)	0.83 4) 2.80 5)	2.42 4) 1.4 5)	25 4) 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
Source : TBE



Use of renewable energy

The substitution of non-renewable energy by renewable energy is in constant progress. In many ceramic production processes, biogenic additives, such as sawdust can be added to the raw clay. The utilisation of such additives offers two advantages. The first one is an additional energy source and the second one is to lighten the products and increase their insulating performance.

This additional energy works by reducing the consumption of fossil fuels and therefore the emission of CO_2.

Biogas reactors at brickwork Gasser/Italy

These additives are primarily selected on technical, environmental and health grounds. They must have a beneficial effect on the product's technical properties; they must not produce harmful emissions or if they do must be amenable to control. And they must not pose a health risk to factory and contruction workers.

Tests determine whether the additives used fulfil these criteria.

2.2.2 Atmospheric emissions: Technical solutions to reduce emissions

Atmospheric emissions are associated with all phases of the manufacturing process.

- Three main kinds of gaseous emissions,
- technical solutions to reduce harmful emissions,
- main measures to minimize dust

Three main kinds of gaseous emission occur:

- Emissions coming from ceramic conversion of the raw material in the kiln. The emissions are HCl (hydrochloric acid), HF (hydrofluoric acid), SO_x (sulphuric acid) and $C0_2$.
- Exhaust gas emissions from combustion processes (from drying and firing plants). The emissions are CO (carbon monoxide), CO_2 (carbon dioxide), NO_x (nitrogen oxides) and particles.
- Emissions due to the use of organic substances (additives). The emissions are VOC's (volatile organic compounds).

Therefore technical solutions are used to reduce harmful emissions.

For gaseous compounds, the main measures are:

- use of raw materials that are low in sulphur, nitrogen, chloride and fluoride
- incorporation of inert additives in the clay body
- incorporation of fine limestone in the clay body to retain fluoride (and some sulphur)
- recirculation of low temperature carbonisation gases into firing zones of kilns (to combust CO and VOC's).
- thermal after burners
- exhaust gas treatment by purification (gravel or lime filter)

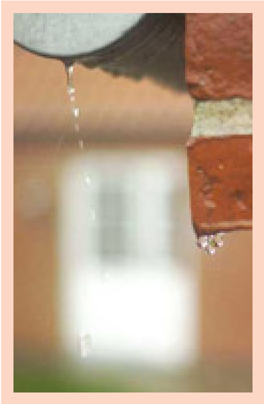
The extraction of clay usually occurs very close to the plant so emissions (CO_2 and NO_x) from transportation are minimised.

Main measures to minimize dust:

- enclosure of dust producing processes
- use of a covered conveyor belt
- use of moist raw materials where possible,
- maintain cleanliness of kilns and kiln cars.

2.2.3 Excess Water

Low rates of water consumption and water wastage are hallmarks of the brick and tile industry.



Water is used both as a raw material and a process fluid for cooling and washing. Some is given off as steam during production.

Some excess water is a by-product of washing operations and its recovery and re-use represents an important factor in the water balance of a clay brick or tile factory. Throughout the industry, the re-cycling of water is widely practised.

2.2.4 Waste materials: insignificant

The environmental impact of our industry's waste is insignificant.

There is no waste in the production process because it is possible to recycle clay at any stage.

The only waste that leaves the factory is from packaging. Paper cardboard and plastic is collected and sent for recycling.

2.3 Economic and Social Aspects

Factories are usually located in rural areas (close to raw material supplies). They generally employ local labour, often for generations, and in so doing help stabilise local communities.

The industry has gone to great lengths to improve its presence in these communities. For example, storage areas are tarred and regularly cleaned in a bid to reduce airborne dust, while fast growing hedges are often planted.

To improve the working environment, measures are taken to reduce dust emission from machinery.

3 Design and Construction

The importance of incorporating sustainability into buildings is now an accepted fact. What is still required is to ensure that participants in the building process understand their role in managing sustainability. This requires that:

- Industry produces the highest quality products,
- Architects create innovative and sustainable buildings,
- Contractors work to established codes of practice.

A weak link anywhere in this partnership can undermine the effectiveness of any sustainable strategy. That is why our industry is communicating with architects, builders, tilers and bricklayers to ensure that the development of innovative techniques and clay products is suited to the needs of the construction industry.

By examining the context of European building and by understanding and accepting its various regional differences, the European clay brick and tile industry is creating products of technical excellence that can lead to sustainable architecture.

More than ever, sustainability remains our driving principle.

3.1 Social Progress

Clay building products have made a major contribution to the built environment which is so much a symbol of the European cultural heritage of the past, and which will continue to be in the future.

3.1.1 What is the context of European building?

It would be wrong to attribute European architecture to one material and one method of construction. Nevertheless, we can justly maintain that throughout Europe, bricks and tiles have shaped the built environment for centuries. Generations of European architects, builders, bricklayers and tilers have used them to build villages, towns and cities.

Such widespread use is not accidental; Europeans have been aware of the technical and aesthetic qualities of clay building products for centuries. The versatility of clay building products has allowed their adaptation to new techniques and methods of construction, while the constant introduction of new colours and sizes and the improvement of technical performance has challenged designers.

As the European building context is constantly evolving, so clay building products are being continuously reconfigured. Innovation allows them to meet the requirements of the 21st century whilst preserving our built heritage.

BRICKS AND TILES FORM THE BASIS OF THE EUROPEAN BUILDING TRADITION! They are the link between our architectural heritage and our future!

3.1.2 Local influences

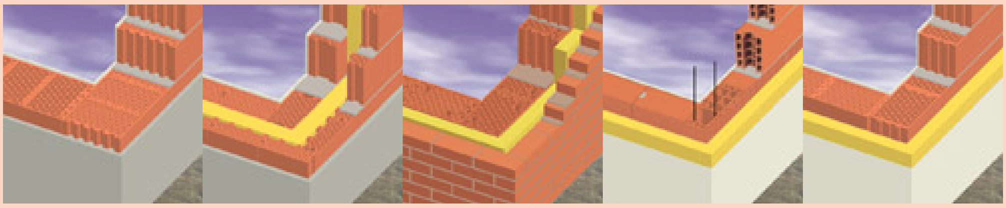
The European building context is more than historical, cultural and aesthetic. Construction methods vary greatly throughout Europe and are heavily influenced by factors such as climate, earthquakes and local traditions.

The different European's requirements of indoor comfort also constitute an important factor. Whatever the climate, our industry develops clay building products that meet these requirements and lay the foundations for a quality indoor climate.

We can find a variety of examples throughout Europe:

Walls

- Cavity wall: vertically perforated unit / cavity / solid unit (facing brick)
- Monolithic wall: monolithic horizontally or vertically perforated unit
- Wall with external or internal insulation



from left to right:
monolithic wall (vertically perforated)
cavity wall
cavity wall with facing bricks
wall (horizontally perforated) with external insulation
wall (vertically perforated) with external insulation

There have also been special masonry constructions devised to overcome seismic considerations.

Roofs

Roof design is dependent on both local tradition and climate and will therefore differ from one area to the next.

- Tiles: Southern Europe tends to use interlocking tiles while in Northern and Eastern Europe the preference is for plain tiles.
- Roof slope: This is determined by climate: generally speaking, the greater the snowfall, the steeper the slope.
- Use of flexible or rigid underlay: in Northern and Central Europe, where snow is common, underlays are used to assure the roof is watertight.
- Tile colour: Natural colours have always been used. The industry has responded to the demands of architects and designers and developed coloured products.

plain tiles

glazed interlocking tiles

roman tiles

In some areas, roof design is determined by seismic considerations.

The clay brick and tile industry exploits this diverse range of design influences to create innovative products and techniques that will be acclaimed by all parties in the design and construction process.

3.2 Environmental aspects

The careful design of clay blocks and roofing tiles and their high quality minimise the environmental impact of building sites and contribute to a high safety level.

3.2.1 Technical excellence of our building products

For generations, brick and tile manufacturers have continually improved the technical properties of their products. Today, this process is achieved in accordance with European Standards.

The characteristics and performance requirements for masonry units manufactured from clay for use in masonry construction are specified in the European standard EN 771-1.

This Standard is linked with test methods for masonry units: EN 772.

The product definitions and specifications for clay roofing tiles for discontinuous laying are specified in the European standard EN 1304.

The European standard EN 1344 specifies the requirements for pavers.

A product standard for beam-and-blocks floor systems exists as draft prEN 15037.

These standards will ensure the high level quality control in the manufacture of the clay building products will be maintained. The introduction of CE marking will confirm that these product fulfil the essential requirements of the European Building Product Directive.

3.2.2 Building in a safe environment

Our industry is dedicated to creating products that will help rationalise the building process.

Construction of a building begins with the transport of materials to the building site. Traditionally, bricks and tiles were produced in rural areas and were linked closely with the life of the local community. Bricks and tiles took on the characteristics of the region from which they came.

Today, our industry tailors its operations around two key developments. The first, is the greater diversity in building products demanded by the market. The second is that it is uneconomic to transport bricks and tiles over long distances.

In dealing with these factors, our industry has been enlarging its range of products in order to ensure availability at local and regional levels. Transport logistics is one of the factors that define the market for bricks and tiles – everything is done to minimise environmental impact.

Storing bricks and tiles on-site

No special measures are required for the safe storage of bricks and tiles on-site. Buildings comprising clay products do not generally impose any risk to the workforce on-site or to people living in the vicinity.

The installation of bricks and tiles requires high standards of manual skill but does not require additional chemicals.

This means that compared to other building sites, such sites tend to have less hazards and are also quieter, less dusty, odourless and less wasteful. Buildings made of bricks and tiles do not cause ground or atmospheric pollution.

The clay brick and tile industry is also striving to improve health and safety on site. Clay blocks, for example, sometime have been ergonomically designed with a griphole to allow safe and comfortable handling.

Also, the very nature of clay building products does away with the need for special protection measures such as masks and gloves, except when cutting.

3.3 Economical aspects

From an economic point of view, it is necessary to stress the requirements of each participant in the creation of sustainable buildings:

- European brick and tile industry: excellence in the products we put on the market, devising innovative clay products and building methods, disseminating the information to all parties involved in the building process;

- architects: design buildings in an innovative and sustainable way;

- bricklayers, roofers and other construction workers: execute their work according to the prevailing codes of practice.

Each party must understand that its role in this philosophy forms part of a total quality concept that takes into account criteria such as context, transport, resource consumption, indoor environment, economics and architectural quality.

3.3.1 Involvement of our industry in sustainability:

Innovation - Information - Training

Our industry wants to create products that are in accordance with the needs of architects and builders. These new products and techniques are designed to improve the quality of the building process at different levels:

- Foster innovation in architectural design
- Allow variety in dimension and colour
- Initiate new techniques and processes

New techniques developed within the European brick industry (glued masonry, pre-assembly process, ...) must be accompanied by the continuous re-training of architects and bricklayers. This requires an involvement at every level (manufacturers, workers, technical advisers, ...) in order to achieve maximum progress.

From an economic point of view, innovation can improve on-site efficiency, reduce build times and as a consequence, reduce costs.

European roof tile manufacturers are also developing more sustainable products, for example, new solar tiles that can be integrated in roofs: hidden completely or well-integrated into the roof.

Industry is also developing new roof tile panels with a cellular structure that can provide thermal insulation and reduce air conditioning needs.

3.3.2 Involvement of architects in sustainability

How to maximise the benefits of high quality bricks and tiles

Many architects and builders are aware that they have to understand the sustainable issues associated with construction. These concepts must be analysed and incorporated at the design stage.

In the first instance, they must take into account "general criteria" such as the orientation of the building, the climate, etc.

Then, they must design the building and choose the materials with which they hope to achieve a sustainable construction.

Building with bricks and tiles asserts our European identity and at the same time, makes for durable and high quality construction.

With clay building products, builders can be sure that they will be using environmentally friendly products that will give them freedom to create diversity of form, colour and texture. This can lead to new forms of building that integrate cultural values in a sustainable way.

Architects must take advantage of the possibilities that clay building materials can offer! They can lead to the creation of an innovative and flexible architecture that can also provide a sustainable option for our present and future needs.

3.3.3 Importance of craftmanship

The durability of clay materials renders them suitable for every type of buildings. Nevertheless an important point that will determine the durability of the construction is skilled craftsmanship. Despite the highest quality European bricks and tiles, bricklayers and roofers must also possess the highest possible skills to enable the successful completion of the project.

4 Building in Use

Clay building products are the best choice for building and its inhabitants.

Whether from ecological, economic or social aspects, clay building products constitute a sustainable option and have favourable lifecycle assessments with comparatively low environmental impact. They are often manufactured in modern, decentralised factories that require low primary energy input and feature equipment to reduce emissions. Due to their good thermal performance, clay building products can enhance the environmental impact of buildings.

Clay building products have a very long lifetime, require little or no maintenance and help minimise heating and cooling costs; they therefore provide optimal economic performance. As a result of these benefits, buildings made from clay building products have a very positive CO_2 balance over their lifetime. Last but not least, they are flexible in use and provide excellent living conditions and indoor climate thanks to their porous structure, their mass and high resistance to fire and moisture.

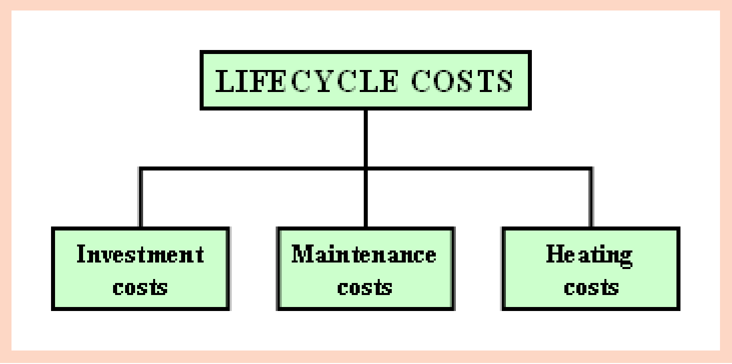
4.1 Economical Aspects

In the past the investment cost of a building was the decisive factor. Today the life cycle cost of a building is becoming a more important yardstick.

However occupants are still interested in the running costs of a building - heating, cooling and maintenance.

4.1.1 Lifecycle costs

The economic evaluation of a building should take into account the whole lifecycle, i.e. costs incurred for investment, maintenance and heating, as well as for disassembly and deposition respectively recycling of materials.



Life-cycle cost analyses for clay brick constructions give very positive results (see e.g. D-A-CH Ökobilanz Ziegel, Dr. Manfred Bruck, 1996). Solid (monolithic) brick walls and cavity walls (incorporating mineral wool insulation) show low lifecycle costs on account of their very low maintenance and their ability to be disassembled and recycled. Higher lifecycle costs are often associated with walls that have external insulation which has to be renewed a number of times during the life of the building.

Lifecycle costs are closely linked to the heating energy consumed by a building so they will also be influenced by the type of energy used, whether electricity, oil, natural gas, renewable energy or district heating.

4.1.2 Investment costs

It is desirable to optimise total lifecycle costs yet it is inconsistent to consider individual costs in isolation. In terms of initial capital outlay, one building construction may cost more than another, but analysed in terms of the respective lifecycles – taking maintenance and repairs into account – the result changes significantly.

A good example of this is the clay brick cavity wall, which – at least in some countries – requires greater capital outlay than, for example, a solid wall with external polystyrene insulation. But the cavity wall has a very long lifespan (at least 100 years) without incurring significant repair costs. In contrast, external polystyrene insulation has a limited lifespan (around 30 years) with additional costs involved on several occasions to renew the insulation. Lifecycle-costs are therefore lower for the clay brick cavity wall.

Investment costs in clay roofing tiles are to be amortized on their one-hundred years lifespan.

4.1.3 Maintenance costs

Maintenance costs for clay brick wall constructions are generally very low because they require little attention over their very long lifespan.

In the case of rendered walls, the only regular maintenance is painting, which may be necessary after 30 years, depending on the location of the building. After 50 to 60 years, the wall has to be re-rendered completely. Clay brick cavity walls normally require no maintenance or repair over their very long lifespan and are highly durable and resistant to environmental pollution. Even when clay brick walls are used with additional external insulation, they will require no maintenance or repair. The only costs incurred will be the renewal at specific intervals of the external insulation. This normally has a shorter lifespan than the clay brick wall and has to be renewed at specific intervals, depending on the location of the building and the type of insulation used.

Maintenance of roof tiles is easy and can be scheduled. It consists in cleaning of vegetal rubble and replacement of broken tiles on a roof that is easily reachable.

4.1.4 Heating and cooling costs

Heating and cooling costs incurred over the lifespan of a residential building are significant. This is not only due to monetary considerations but also to the need to reduce CO_2 emissions from residential heating systems – seen by EU-member states as important constituents in meeting their Kyoto targets.

Heating costs are directly linked to the energy consumed by a building, which is itself influenced by many factors. These include:

- building location / climate
- building geometry (size, shape, volume/surface ratio)
- thermal performance of the building envelope (U-values)
- thermal mass (thermal capacity to exploit energy gains)
- ventilation
- heating system efficiency
- number of occupiers and their lifestyles

In reality the choice of energy (electricity, oil, natural gas, renewable energy such as wood or solar heating and district heating) used for heating or cooling can be much more decisive for heating and cooling costs than the type of wall construction. Electricity is often the most expensive heating energy. Other options include oil, natural gas, renewable energy (wood or other biomass, solar heating) and district heating. The last two possibilities are normally cheap, but this will depend on location and future trends.

New developments in clay roof tile technology reduce heating costs for the house. Cellular structure of new clay roofing panels can isolate the house from heat in summer and cold in winter. New solar tiles are being designed as solar collectors to heat transfer fluid and produce renewable energy that can be used in the house.

4.2 Environmental aspects

The choice of building materials was often influenced by single ecological aspects of a product. Today one finds that a more holistic approach is favoured when the product is assessed.

4.2.1 Heating energy consumption of the building

The following picture shows the average contribution to energy losses made by the various elements of a properly insulated detached house:

The heating and cooling energy consumed by a building will depend on various factors:

Location of the building / climate:
The colder the climate, the greater the energy needed for heating although this can be reduced by the intensity of solar heat gains during the year.

Geometry of the building (size, shape, volume/surface ratio):

The smaller the building, the higher the specific heating energy consumption. But a simple shape (ideally a cube) and a high volume/surface relation (a big volume with a small surface) means lower heating energy consumption.

Thermal performance of the building envelope (U-values of walls, windows, roof, cellar)

U-values will depend on the type of wall construction. Building regulations vary from country to country and required values will depend on the local climate. The lower the U-values of external building elements, the lower the energy required for heating. It has recently been shown that solid clay brick walls can reach U-values as low as 0.20 W/m^2K. Clay brick cavity walls and clay brick walls with additional insulation can in principle reach any required U-value by varying the insulation thickness. In many countries the trend is toward low energy houses (LEH, heating energy requirement approx. 40-60 kWh/m^2a) or even passive houses (PH, heating energy requirement < 15kWh/m^2a).

For these energy standards, the following U-values are necessary:

Building element	LEH	PH
	U-value [W/m^2K]	
External wall	0,30 - 0,20	≤ 0,15
Roof / top floor	0,15	0,10
Foundation / cellar	0,30 - 0,20	≤ 0,15
Windows (U_F)	1,50 - 1,20	≤ 0,80
Doors	1,60	1,00
Thermal bridges	+	+++

Especially in houses that have very low energy consumption it is important to take into account thermal (cold) bridges.

Thermal mass to use energy gains

When considering the internal environment of a building, it is important – especially in summer – to have sufficient thermal mass to store the solar energy absorbed by the construction (see also Living comfort and Internal environment). Thermal mass has a direct effect on the energy required for heating. Massive clay brick walls can store solar heat gains and radiate the energy out when it is needed, whereas lightweight constructions cannot exploit this energy or only small parts of it.

Ventilation of the building

The lower the energy consumed to heat a building, the higher will be the effect of heat losses through ventilation. For low energy or passive energy houses, this is a significant part of the total heat loss (i.e. over 50 %). In several countries, state of the art mechanical ventilation systems incorporating heat recovery are now common. These ventilation systems reduce the heating energy requirement by an average 20 kWh/m²a and when combined with monolithic external clay brick walls can help attain passive house standards.

Efficiency of the heating system

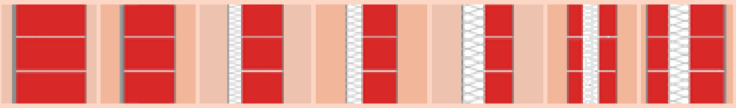
The total energy consumption of a building also depends on the efficiency of the heating system. Normally electric heating systems have the lowest efficiency; modern gas boilers or heat pumps have a high efficiency.

Lifestyles of householders

People's lifestyles have a significant effect on overall thermal efficiency. Research has shown that careless actions and routines can triple the energy required to heat a building. Excessive ventilation, such as windows open all day even in winter, can negate the benefits otherwise associated with energy efficiency measures featured in the construction. It is therefore important that householders have good awareness of energy efficiency.

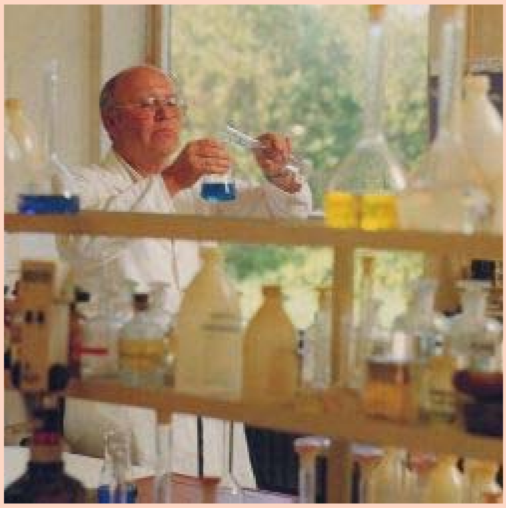
The following table gives the heating energy consumption for different clay brick wall types on a typical 18-apartment residential block (see picture above). The wall constructions were chosen on the basis of their high level of thermal insulation. The consumption was calculated with different sets of U-values for the other building elements (roof, windows, doors, basement, etc.) – the first 2 lines show the results of the calculation with good practice U-values (first line without, second line with mechanical ventilation system), the last line ("minimum") shows results with the lowest available U-values on the market.

Products	50 cm	38 cm	30 cm	25 cm	20 cm	cavity	cavity

	mono-lithic block	mono-lithic block	block +10 cm insul.	block +12 cm insul.	block +16 cm insul.	wall 10 cm insul.	wall 15 cm insul.
U-value wall	0,27	0,37	0,24	0,25	0,20	0,34	0,20
Thickness (cm)	54	42	42	39	38	39	56
wall construction							
Heating Energy Consumption (kWh/m²a)							
without vent. system	43	46	40	41	38	45	40
with vent. system	24	28	22	23	20	26	21
minimum	17	20	14	16	13	19	13

4.2.2 Environmental impact of building materials

The clay brick and roof tile industry was first in the building materials sector to provide an ecobalance of its products. Based on the life-cycle assessment of several factories in different countries, the average environmental impact of 1kg bricks was determined. Factors considered included:



- Demand for renewable energy resources (MJ)
- Demand for non-renewable energy resources (MJ)
- Greenhouse effect (kg CO_2-equiv.)
- Ozone depletion (kg R11-equiv.)
- Photosmog (kg Ethylen-equiv.)
- Acidification (kg SO_x-equiv.)
- Nitrification (kg PO_4^{3-}-equiv.)

The results show that clay products have a low environmental impact compared with other building materials. (see also **GBC - the green building challenge handbook –> "Building materials"**)

It is also possible to determine the environmental impacts per m² of construction. Based on life-cycle assessments of several factories, the ecobalance of clay products (facing bricks, roofing tiles, clay blocks) has been established and the average ecological impact of one square meter of clay contruction in one year was determined. The **results** (see Démarche HQE) show that clay products have a low environmental impact.

4.2.3 Lifecycle assessment of the building

One aspect of the clay brick ecobalance project based on lifecycle assessments of clay brick factories in several countries was the "cradle to grave" assessment of clay brick wall constructions. This forms an essential part of the overall lifecycle assessment of a whole building.

The results of the evaluation of different clay brick wall constructions were:

- The ecological assessment of buildings must take into account the whole lifecycle of the construction. This covers:
  - Raw material extraction,
  - Manufacture of building materials,
  - Erection of the building,
  - In-use phase,
  - Maintenance and repair,
  - Demolition,
  - Separation and re-use,
  - Removal of building residues.

- The choice of heating system and the type of fuel used have a significantly higher influence on the lifecycle assessment than the wall construction and its thermal performance.

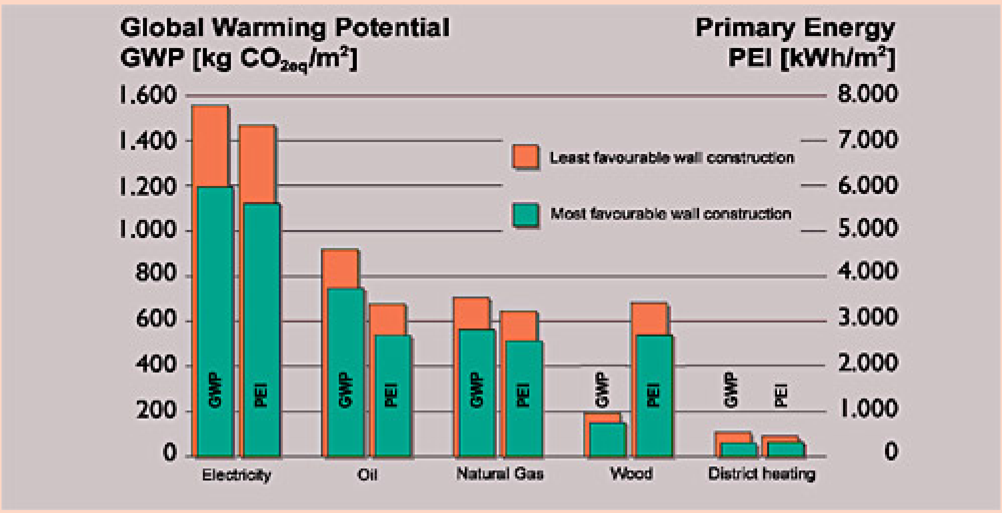
- District heating from waste incineration has the least impact on global warming whereas electrical heating has the highest impact (but this will also depend on the method of power generation). Natural gas and oil heating fall between these two extremes.

- Where heating systems are already highly efficient, the potential to recycle the building's materials becomes significant in the overall calculation.

- Taking these points into account, monolithic clay brick walls and clay brick cavity walls with sufficient thermal capacity achieve excellent results.

- The results are more or less independent from the established evaluation model.

Ecological lifecycle assessment



The graph above depicts the results of an ecological lifecycle assessment of clay brick wall constructions in terms of GWP (Global Warming Potential) and PEI (Primary Energy Input) for various fuels and heating systems over a period of 90 years.

In reality the choice of energy (electricity, oil, natural gas, renewable energy such as wood or solar heating and district heating) used for heating or cooling can be much more decisive for the ecological assessment of a building than the type of wall construction.

Note: these results can vary significantly from country to country and will depend on the prevailing type of power plant and on the availability of district heating from waste incineration.

Within the Green Building Challenge Project, evaluation tools have been developed to determine the overall ecological lifecycle assessment of a whole building. These models have been implemented in several countries (e.g. **"Total Quality" certification in Austria**). In France the Démarche HQE is used (see **Démarche HQE**).

The results of the evaluation for clay brick buildings are very positive.

4.2.4 CO_2-balance of the building

The table below shows the environmental impact of 1 kWh of heating energy (depending on the fuel/energy used) (go to **GBC - the green building challenge handbook**):

	Funct. Unit	Global Warming Potential	Acidification potential	Primary Energy Input
Unit		kg CO_2 equ./kWh	kg SO_2 equ./kWh	kWh/kWh
Oil	kWh	0,313	0,719	1,317
Natural gas	kWh	0,263	0,320	1,319
Electricity	kWh	0,576	3,957	3,770
Wood chips	kWh	0,014	0,540	1,369

The above data when used with heating energy consumption values will allow a simple calculation of the CO_2 balance of a building over a one year period. For example, if the heating energy consumption is 50 kWh/m²a and the house has an area of 150 m² and a natural gas heating system, the total CO_2 output (GWP) is 0.263 x 50 x 150 = 1.972,5 kg CO_2 equivalent.

Compared to the CO_2 produced by a building's heating system, the CO_2 emissions caused by the production process of bricks and clay blocks are very low. The GBC-study of the clay brick industry in Germany, Austria and Switzerland (see **GBC - the green building challenge handbook –> "Building materials"**) shows a GWP value of 0.194 kg CO_2 equivalent per kilogram of clay bricks. A 150 m² family house will involve on average the use of 40 tons of clay bricks or blocks that will generate 7.760 kg of CO_2 during their manufacture. In other words, the CO_2 output resulting from four years of heating exceeds the CO_2 caused by the manufacture of the bricks.

Normally, mass brickwork has an average life of at least 90 years. If the CO_2 output caused by the brick manufacture is divided over 90 years, the average annual CO_2 load is only 86 kg CO_2, or 4,4% of the CO_2 produced by the heating system.

4.3 Social Aspects

Clay buildings have a positive effect on the health and well-being of the occupants.

4.3.1 Living comfort

Brick-built buildings offer high levels of comfort although we all have our own ideas about what constitutes a comfortable environment. Although some of these ideas are difficult to quantify, others can be clearly measured or tested. These include:

- acoustic performance / sound insulation,
- thermal comfort (surface temperature of walls, difference between surface and room temperature, air movements in the room),
- ability of the wall to absorb moisture and return it to the indoor air,
- thermal mass / heat storage,
- no toxic emissions emanating from the building fabric into the internal environment,
- high levels of safety in case of fire, flood and burglary,
- high levels of flexibility inherent in the building's design.

4.3.2 Indoor climate

The indoor climate can have a significant effect on an occupant's sense of well-being and clay brick walls perform very well in this respect. Due to their very good thermal performance in solid, cavity and externally insulated walls, the temperature of the inside surface is high even when it is cold outside. It is important for comfort that the difference between indoor surface temperature and indoor air temperature is minimal. Air movements due to temperature differences or to imperfections in the external construction should also be minimal.

The porosity of clay bricks allows them to absorb moisture from the air when the relative humidity is high and to return this moisture when the indoor air becomes drier. In addition to moisture, clay brick walls can also absorb and store solar heat gains, a fact that can lead to a balanced climate in summertime. This is in contrast to lightweight constructions that often suffer from summer overheating.

Special attention must be given to thermal (cold) bridges such as may occur at corners and window frames, where surface temperatures are significantly lower. The clay brick industry can provide design solutions to minimise the effect of these details. For further construction details see **VÖZ Baudetails**.

Clay roof tiles contribute to:

- hydrothermal comfort by protecting the building from solar overheating, rain and snow
- acoustic comfort by reducing the impact noise of precipitations on the roof.

4.3.3 Safety (water, fire, housebreaking, earthquake, etc.)

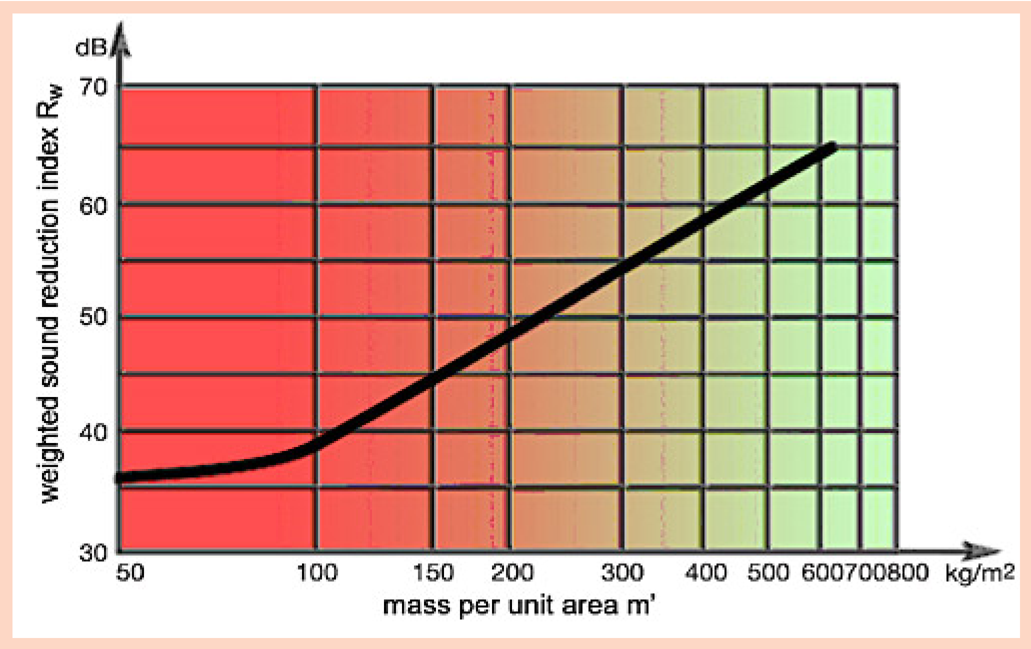
Clay bricks are non-combustible, provide excellent fire resistance and do not emit any hazardous substances or gases. Furthermore, they do not normally suffer structural damage during a fire and can therefore continue their load-bearing function after the building has been refurbished.

Clay brick walls can also withstand saturation from flood water and burst pipes without being adversely affected structurally. They can withstand horizontal loads, such as those from earthquakes, but need to be reinforced in areas subject to high seismic disturbances. They also provide high levels of security from intruders.

Clay roofing tiles are inert materials. Therefore, they are non-flammable and there is no emission of toxic gases in case of fire. Rainwater run off can be collected and stored for use.

4.3.4 Acoustic protection / sound insulation

In principle, the sound insulation of a wall or floor will depend on its mass. Therefore mass construction buildings, such as those of brick, will have a much better acoustic performance than those of lightweight construction.



4.3.5 Flexibility in use

Clay brick buildings are very flexible. Changes are possible both during the construction process and throughout the building's life, when social changes may dictate changes in the layout.

5 Demolition and Recycling

The last phase in a product's life cycle can become the first, if demolition is followed by recycling and re-use. Despite the potential long life of clay brick buildings (well in excess of a 100 years), they are sometimes demolished well before the end of their useful life. The text below examines the options for re-using ceramic building materials.

A research project carried out by TBE in the late 1990s concluded that the following are possible uses for recycled clay building materials:

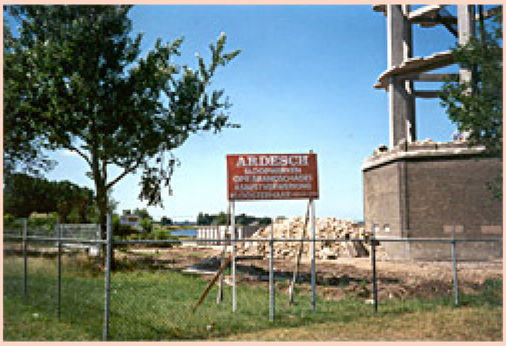
- Reclaim as bricks and tiles
- Filling and stabilizing material for infrastructure works
- Aggregates for in-situ and precast concrete and mortars
- Aggregates for calcium silicate bricks
- Tennis sand
- Plant substrates
- Other options

Building & demolition waste is used extensively throughout Europe for roadworks and for use as aggregate. This is facilitated by fast developing recycling technology that allows precise extraction of various materials from mixed demolition waste. Separating out ceramic matter provides an opportunity to recycle and re-use a very sustainable building material.

5.1 A longer life for buildings

Where sustainability is important, demolition should be the last resort but if unavoidable, other options can be considered. Because bricks and tiles are highly durable materials, they can be re-used after a building has been demolished. Buildings should be designed with as long a life as possible. This constitutes a more efficient use of buildings and materials and reduces the amount of demolition waste. Buildings should also offer flexibility, so that after they have come to the end of their original purpose, they can be refurbished for other uses without having to resort to demolition.

5.2 Demolition of buildings



When the only option is to demolish, ways must be found to re-use as much as possible of the building fabric.

Extracting roof tiles and storing them for re-use is not difficult. And when bricks are left over from building projects, they too can be diverted to other uses. But utilising bricks from demolition sites is more difficult, as they may be contaminated with concrete, mortar, plaster and other materials.

5.2.1 Volume of masonry waste material

recycling facility

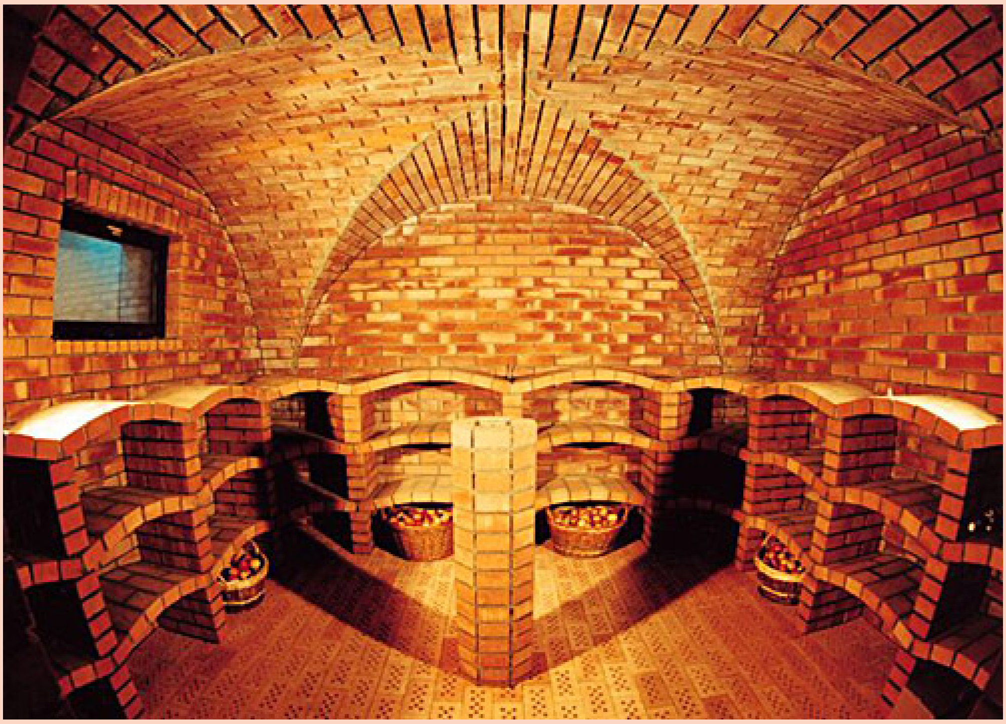
The amount of brick demolition waste that is re-used varies across Europe. In several countries, more than half of all demolition waste is re-used in some form, although at present this is often for low-grade applications. Difficulties may however occur when separating-out materials, particularly where composite elements have been used. This is why ease of separation and compatibility of certain combinations of materials should be in the minds of designers and specifiers. In some countries, studies have been conducted to highlight methods of re-using bricks from demolition sites.

But it seems certain that economic and legislative pressures will have a profound effect on the process of recycling building materials.

5.2.2 Main environmental criteria for re-use

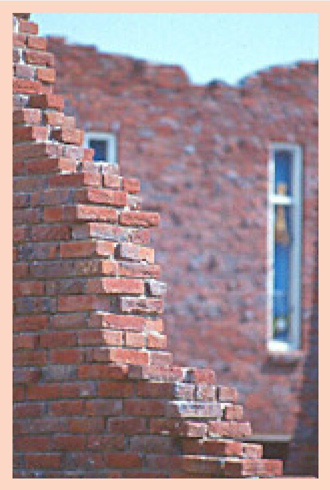
The technical criteria for re-using ceramic demolition waste are few. In most cases, demolition waste is mixed-up with other material, but needs to be free of contaminating elements such as heavy metals and PAH's. Re-using demolition waste in infrastructure projects is not normally a problem, unless it ends up in landfill.

The European Commission is working on rules to prevent the contamination of soil, groundwater or surface water caused by landfill material. But as ceramic building materials are made of natural clay, they do not pose a danger to the environment.



wine cellar made of recycled bricks

5.3 Demolition and recycling - European Policy



The European Commission is formulating a strategy for the reduction and recycling of waste. There are no barriers for the use of granulated ceramic material. But unfortunately, it is often mixed with contaminated demolition waste. If this is purely brick masonry it is not a problem when converted to landfill, as generally contact between ceramic material and ground or surface water causes no toxic side effects. After all, bricks and tiles in service are frequently exposed to ground and surface water and do not normally pose a threat.
For a more sustainable construction, ceramic building products should be incorporated into flexible buildings with long design lives in order to ward off the spectre of demolition for as long as possible. Ceramic products are certainly very durable and will stand the test of time to prove they are truly sustainable.

5.4 Options for recycled brick material

A research project carried out by TBE in the late 1990s concluded that the following are possible uses for recycled clay building materials:

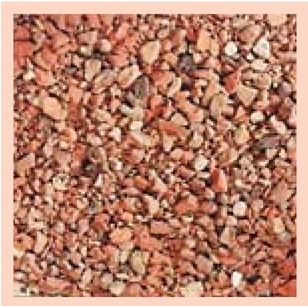
5.4.1 Filling and stabilizing materials for infrastructure

Minor roads

Masonry waste and scrap bricks have for many years been used to fill and stabilise minor roads, especially in wet areas such as woods and fields. The practice is common in countries that lack adequate stone supplies such ad Denmark. The material is generally used uncrushed.

Main roads

Crushed clay bricks, roof tiles and other masonry can be used on larger road building projects, especially as unbound base material. It is used to build roads in countries that include Switzerland, Holland, UK and Denmark.



Although crushed masonry can be used for lightly trafficked roads, it is not suited to heavy traffic due to the risk of deformation.

The material replaces natural materials, such as sand and gravel, which are normally used in large amounts for this purpose. In some cases, crushed masonry can form part of a mix that may also contain concrete and natural aggregate.

In both cases, the material has to be free of non-ceramic contaminants that may be leached by water to cause pollution. Scrap bricks, roofing tiles or selectively demolished masonry do not normally pose a problem unless they are contaminated with impurities such as mineral wool and concrete.

Although energy is used in demolishing and transporting the reclaimed material to the point of re-use, the use of ceramic material can have a lower embedded energy than the use of ‘virgin’ raw materials. Indeed, using demolition waste in small roads may even result in less energy usage in forestry and agriculture equipment.

5.4.2 Aggregates for in-situ and precast concrete and mortars

Crushed clay bricks and other masonry can also be used to level and fill pipe trenches. The crushed material will replace natural materials such as sand and will therefore cause fewer disturbances to the landscape.

A fine grain size of around 0-4 mm is normally used for pipe trench material and this can mostly comprise crushed masonry material. Coarser particles can be used for other applications (e.g. aggregates in concrete and mortars).

Crushed masonry that is used for this purpose must be free of contaminants that can be leached by water to cause ground water pollution.

5.4.3 Aggregates for calcium silicate bricks

Crushed clay bricks, tiles and other masonry can also be used as aggregate in cast concrete. The crushed material replaces other raw materials such as sand and causes fewer disturbances to the landscape.

The production of crushed masonry aggregates for concrete involves crushing, sorting and cleaning the demolition waste.

The main environmental impact of this process is the production of dust during crushing and sieving. The problem can be minimised by sprinkling with water and is comparable to problems connected with the production of natural aggregates.

Several European research projects have explored the potential of using crushed masonry as aggregate for concrete. It is common practice in Austria, Switzerland, Denmark and especially Holland.

Sand for surfacing tennis courts is produced by crushing red bricks and roof tiles.

The material is produced by crushing in hammer mills to a grain size of 0-2 or 0-4 minimum. The process is most efficient when it occurs at brick or tile factories where there is an abundance of scrap material. Different bricks will give different qualities and colours of tennis sand. Clinker quality will have numerous benefits:

- Better water drainage
- Unique colour
- Greater density (less wind scatter)
- No moss problems

Dust may arise during production but the problem can be minimised by enclosing the crushing equipment and if necessary, using water sprayers.

The requirements for sand and other materials used in tennis courts may be laid down in standards and specifications stipulated by tennis governing bodies. The main requirements are water permeability, grain size distribution, surface shear stability and a satisfactory proctor test. The fine surface layer is laid over courser-grained layers that can comprise crushed clay brick matter.

5.4.5 Plant substrates

Crushed bricks and tiles can also be used to form substrates for growing plants. The material may be mixed with other substances used in plant production, e.g. composted organic materials. This material is especially suited for green roofs. Flat roofs are covered with a dense polymer membrane and overlaid with 10-30 cm of the crushed brick and tile material.

In research projects, this material has compared well with other materials used for the same purpose e.g. expanded clay and lava. The porosity of the material allows it to retain water that plants can draw on in dry periods. The use of a lighter coloured material can lower evaporation and thus enhance soil moisture levels.

Another possibility for crushed bricks and masonry is as fill material around tree roots where traffic would otherwise compact the soil and hinder its ability to absorb air and water.

The use of recycled ceramic waste material will save on new raw materials, but it must be free from contaminants that could be leached by water and adversely affect the plants and the surrounding area.

5.4.6 Other options

The above-mentioned options for recycling clay bricks and roofing tiles are the most notable. In some countries (e.g. the Netherlands) a possible reduction of masonry waste from infrastructure works is expected to occur in a few years. This will dictate the need for new national and regional strategies.

applications of reused bricks

Bricks and roof tiles have traditionally been regarded as important materials as after demolition they have often been incorporated into new buildings. In many countries, this traditional way of recycling is still used. By using old bricks and tiles, it is possible to endow buildings with a unique appearance.

However, it should be remembered that:

- Cleaning bricks is time consuming, difficult and dusty work that, if mechanised, is rarely successful. New techniques should be applied to tackle such problems.
- Cement rich mortars are difficult to remove. In countries like Greece, where mortar from ancient constructions is a full ceramic material, it does not need to be removed.
- Excess mortar dust can inhibit the adhesion between mortar and bricks and lead to weaker masonry, depending on the mortar composition.
- Bricks from demolished buildings may vary in quality. It is therefore difficult to assess the strength and load-bearing capacity of masonry made from recycled bricks. European and national standards are very strict and it is extremely difficult to be sure that recycled bricks used in new structures will be durable.
- Due to the difficult nature and high labour costs associated with the process, the use of recycled bricks may be more expensive than the use of new bricks.

The stability and porosity of recycled brick renders it suitable for use as a fill or surfacing material in roads and trenches. Other possibilities will no doubt be found for future applications. Bricks, roofing tiles and other recycled masonry have chemical compositions that may be compatible for use with other building products fired at high temperatures. Possibilities therefore exist for combinations with materials such as cement and mineral wool.

Finely ground clay brick and roofing tile materials have a pozzolanic effect. Due to the presence of reactive silica, the material can form a binding mixture when mixed with lime or lime-containing materials, such as cement. This effect can be used in mortars and concrete. The practice was adopted by the Romans and exploited by numerous cultures ever since. Current investigations may show that this is an important use for recycling clay bricks and roof tiles.

Scientific institutes and universities are embarking on an increasing amount of research to further our knowledge in this sphere. In the Netherlands, one project studies the separation of mixed building and demolition waste materials and the re-use of each type.

After selective demolition, heat is used to remove mortar from bricks in order to allow re-use in housing. In cases where the mortar is a full ceramic material, as in Greece, separation would not be needed and would thus render re-use a lot easier.

In all other cases where bricks and mortar are separated, tests have shown that the whole brick still conforms to technical standards. This proofs that ceramic building products have enduring qualities that are suited to sustainable construction.