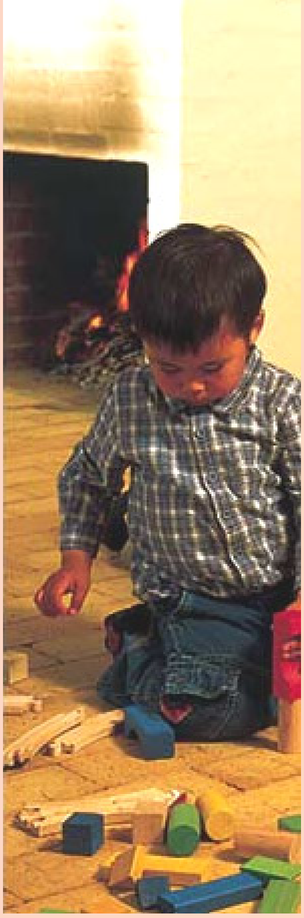
4 The Clay Life Cycle - Building in Use



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.

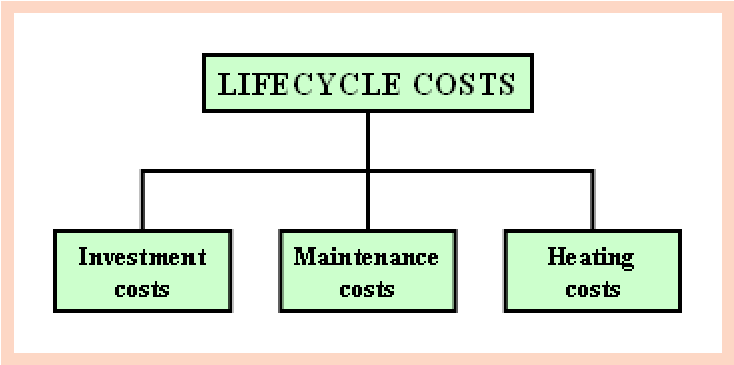
4.1 Economical Aspects

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/m²K. 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/m²a) or even passive houses (PH, heating energy requirement < 15kWh/m²a).

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

Building element	LEH	PH
	U-value [W/m²K]	
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

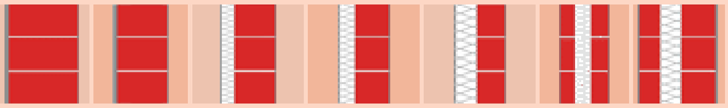
The total energy consumption of a building also depends on the efficiency of the heating system. Normally electric heating systems have the lowest efficiency; modern gas boilers or heat pumps have a high efficiency.

Lifestyles of householders

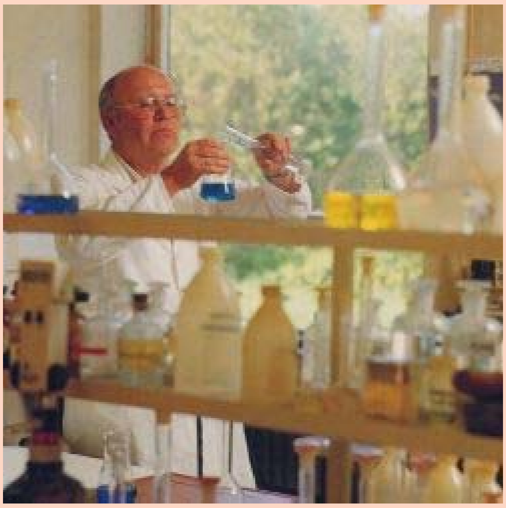
People's lifestyles have a significant effect on overall thermal efficiency. Research has shown that careless actions and routines can triple the energy required to heat a building. Excessive ventilation, such as windows open all day even in winter, can negate the benefits otherwise associated with energy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

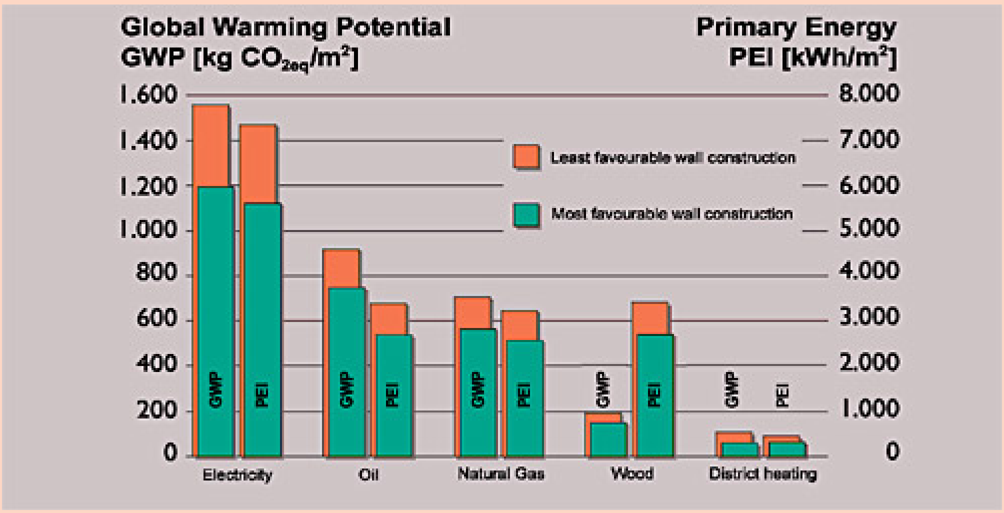
- District heating from waste incineration has the least impact on global warming whereas electrical heating has the highest impact (but this will also depend on the method of power generation). Natural gas and oil heating fall between these two extremes.

- 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.

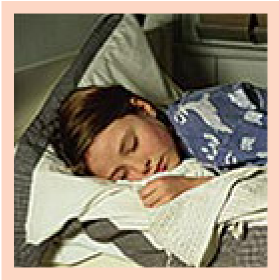
4.3.3 Safety (water, fire, housebreaking, earthquake, etc.)

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.

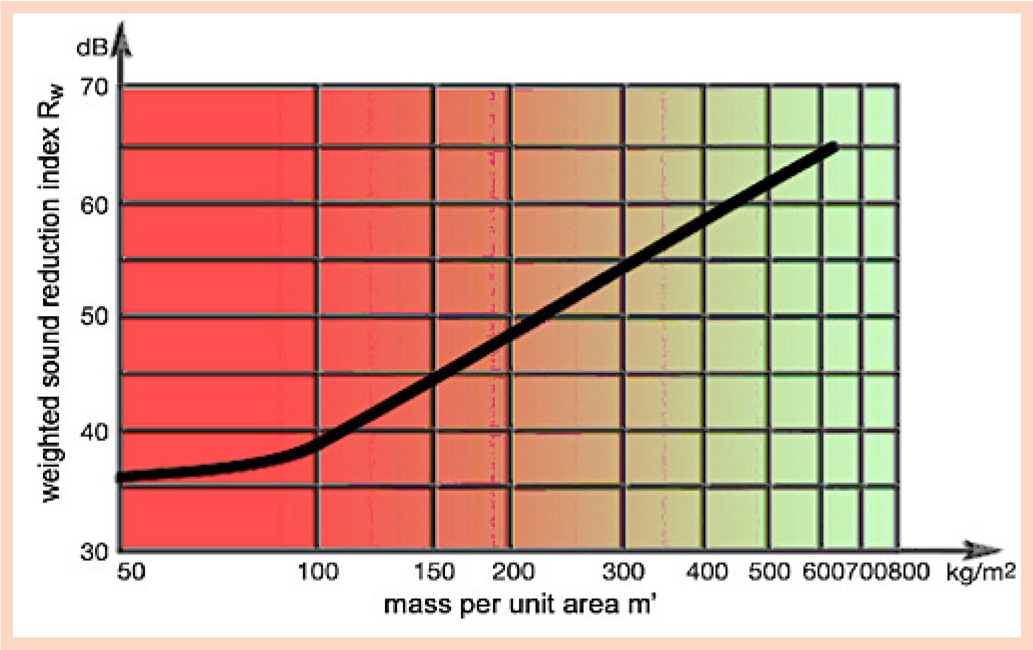
Clay brick walls can also withstand saturation from flood water and burst pipes without being adversely affected structurally. They can withstand horizontal loads, such as those from earthquakes, but need to be reinforced in areas subject to high seismic disturbances. They also provide high levels of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