MEDITERRANEAN

Pollution Prevention in the **Structural Ceramics Sector**

CLEANER production

Regional Activity Centre for Cleaner Production (RAC/CP)
Mediterranean Action Plan

UNEP

MAP

Regional Activity Centre for cleaner Production

Ministerio de Medio Ambiente España

Generalitat de Catalunya
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Please inform us if any point in the study can be improved or if any inaccuracy is found.

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CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

INDEX OF IMAGES

1. INTRODUCTION

The situation of the construction sector (which has experienced a major boom in the majority of Mediterranean countries) is one of the main factors affecting production levels among the industries within the structural ceramics sector.

This has meant that in recent years, the structural ceramics sector has become one of the most important sectors in terms of production.

In addition to this, it is a sector with a large number of family businesses, but one that is in constant evolution in order to adapt to new market demands. This results in the need to adopt new technologies and to keep up to date with increasingly strict environmental requirements.

The main products produced by this sector can be grouped into different families:

- Bricks
- Roofing tiles
- Hollow bricks
- Blocks
- Paving slabs
- Setts
- Lattice tiles
- Cladding tiles
- Panels
- Others

Strong competition and the new ways of working emerging in the field of construction, particularly those involving construction solutions for interior building work consisting of sheets of laminated plaster, which provide quick, clean and economical construction solutions, mean that it is necessary to find new forms of exploiting structural ceramics. As a result, studies in this sector have multiplied in recent years.

Promotional campaigns for the product that have been initiated by a number of guilds in the sector have grown from these initiatives.

The availability of specific training in structural ceramics has increased, and this in turn helps supervisors and workers in general to become aware of the importance of this sector and the possibilities that should be exploited in order to ensure continuous improvement, both in processes used and in the development of new products.

Historically, environmental actions in companies manufacturing ceramics have been limited to very specific treatment processes for gases emitted, without promoting actions involving a global approach to the production process. The incorporation of environmental criteria into the whole process can lead the management of companies to implement greater eco-efficiency, leading in turn to increased competitiveness.

1.1. AIMS

Increasingly strict environmental regulations and legislation, together with the greater awareness of the population at large with regard to the need for environmental protection, have led society to demand that companies incorporate greater respect for the environment into their production processes. All of these points mean that there is a need for companies to include aspects related to environmental protection in their production management.

This manual is intended for companies of different types that are classified as part of the structural ceramics sector. Its aim is to provide real solutions that can be the first step in a move to minimise consumption and waste flows at source, avoiding the need for final treatment as far as possible, given that this approach uses more expensive and less effective solutions.

The recommendations contained in this document are intended to encourage the reduction at source of pollution by means of changes in the manufacturing process, the application of good practices, changes in materials and products and the use of technologies that are more respectful of the environment.

1.2. THE STRUCTURE OF THIS MANUAL

This manual has been structured according to the following points:

Chapter 1 introduces the manual and gives an outline of its aims and structure.

Chapter 2 provides a general overview of the situation of the sector in each of the countries of the Mediterranean region, with special emphasis on those countries with greatest production and international presence.

In addition, this chapter studies the characteristics of the sector, starting from the raw materials from which the clays that will form the fired ceramics are obtained, and then looking at the preparation process of this raw material.

The main fuels used in the manufacture of structural ceramics (natural gas, petroleum coke, fuel oil, coal and biomass) are also detailed.

Chapter 3 analyses the main phases in the production of ceramic products: receipt and storage of raw materials, grinding, shaping, drying, firing, storage of the product and other auxiliary processes. The associated technologies and a flow chart with the inputs to and outputs from the process are described for each phase, as are the associated environmental aspects.

Chapter 4 goes over the main environmental aspects affected by the manufacture of structural ceramics, such as water consumption, energy consumption, waste generation, noise generation, production of wastewater and atmospheric emissions.

In **Chapter 5**, the main fuels used in the structural ceramics sector at present are described, analysing the characteristics and environmental efficiency of each of them. A study is carried out into the possible introduction of changes to the combustion process in order to improve consumption, and therefore efficiency.

Chapter 6 contains a description and analysis of actions encouraging waste reduction and recycling at source. In addition, improvements are proposed, such as the redesigning of products and processes, together with other alternatives likely to minimise the production of waste and emissions, or to reduce the impact that these can have.

Chapter 7 contains different case studies of the application of pollution prevention measures in structural ceramics industries.

Chapter 8 gives an outline of the main conclusions drawn by this manual.

2. THE STRUCTURAL CERAMICS SECTOR

The companies grouped in this sector produce bricks, roofing tiles and other fired clay products, and are included within the group of industries involved in the manufacture of non-metal mineral products. Energy consumption is an area of major importance within the total costs of these companies.

This is a sector that is linked strongly to the evolution of economic cycles and construction activity.

These industries are generally located near to the site where the raw materials used are obtained, and also close to centres of consumption, in order to minimise the transport costs of products with low added value.

The production processes of bricks and ceramics include mechanical treatment, consisting of the extraction and preparation of clays and other materials, the shaping of objects, drying, firing in high-temperature kilns and the finishing of the product.

Construction, including new construction and renovation works, is a determining factor in the level of market activity for structural ceramics. This activity is linked to:

- The level of investment in client sectors (industry, services and administration) in construction, extension and renovation projects in the places of production, administrative areas or logistical areas.
- The need for the renovation of houses.

Construction can be classified according to two criteria:

- The final use of the work carried out:
  - **Residential:** purely individual dwellings (detached houses), grouped individual dwellings (individual houses constructed under the same licence), collective dwellings (buildings for several dwellings) and residential dwellings (hostels, university residences, barracks, guest houses, hotels, motels, holiday camps, etc.).
  - **Non-residential:** agricultural, industrial and commercial constructions, office buildings and teaching centres.
- The nature of the work carried out:
  - **Original construction work:** building work for the new construction of buildings, including individual turnkey houses and assembly and raising work.
  - **Secondary construction work:** finishing work (frames, covering, insulation, carpentry, glazing, installation of electricity or heating, plasterwork, paintwork, etc.) together with restoration and refurbishment work.

2.1. THE SITUATION OF THE STRUCTURAL CERAMICS SECTOR IN THE MEDITERRANEAN REGION

This section is intended to provide a general overview of the economic situation and of the construction and industrial ceramics sectors in the different countries that make up the Mediterranean region.

The twenty countries covered by this study, and which make up the Mediterranean littoral are as follows:

- Albania
- Algeria
- Bosnia and Herzegovina
- Croatia
- Cyprus
- Egypt
- France
- Greece
- Israel
- Italy
- Lebanon
- Libya
- Malta
- Monaco
- Morocco
- Slovenia
- Spain
- Syria
- Tunisia
- Turkey

The main economic indicators of the countries making up the Mediterranean region are detailed below:

Table 2.1: Economic indicators for the countries of the Mediterranean region

	AREA (KM^2)	GDP (€)	GDP IN R&D (€)	GDP PER CAPITA	POPULATION (INHAB)
Albania	28,750	4,806,966,483	1,105,602,291	1,932.57	3,169,000
Algeria	2,381,740	51,797,458,850	16,057,212,243	2,073.09	31,833,000
Bosnia and Herzegovina	51,200	5,465,502,446	1,093,100,488	1681,962172	4,140,000
Cyprus	9,250	8,935,724,356	0.00	14,785.14	770,000
Croatia	56,540	22,230,275,245	6,002,174,316	1716.128857	4,456,000
Egypt	1,001,450	64,696,938,073	10,998,479,472	1220.076288	67,559,000
France	551,500	1,371,981,512,713	260,676,487,415	29,267.02	59,725,000
Greece	131,960	13,582,245,338	31,239,164,278	16,202.68	10,680,000
Israel	21,060	-	-		6,688,000
Italy	301,340	1,150,578,935,068	230,115,787,013	25,429.26	57,646,000
Lebanon	10,400	14,913,206,307	2,535,245,072	4,224.14	4,498,000
Libya	1,759,540	-	-	-	5,559,000
Malta	320	-	-	-	399,000
Monaco	2.00*	-	-	-	32,100
Morocco	446,550	34,920,755,750	8,031,773,822	1,477.46	30,113,000
Slovenia	20,250	20,630,417,606	2,415,985,769	13382.98552	1,964,000
Spain	505,990	656,253,908,879	415,138	20342.57786	41,101,000
Syria	185,180.00	16,888,479,441	3,884,350,271	1,237.73	17,384,000
Tunisia	163,610.00	19,058,902,919	4,764,725,729	2,453.97	9,895,000
Turkey	774,820.00	186,783,939,870	39,224,627,372	3,365.37	70,712,000

Source: World Bank, 2003
**Source: www.socialwatch.org*

The Mediterranean region is characterised mainly by its high capacity for exporting and importing, due to its geographical location, which allows it to use marine transportation for these.

The high levels of activity in countries such as Spain and Italy, two of the main global producers of structural ceramics products, should be highlighted. In particular, Italy is the largest producer of ceramics, contributing 15.3 % of global production. Spain is the second producer in the world, with a contribution of 15.1 % of the total volume produced. The next two countries come a long way behind these two countries: Turkey, with 4.2 % of the global total, and France, with 1 %.

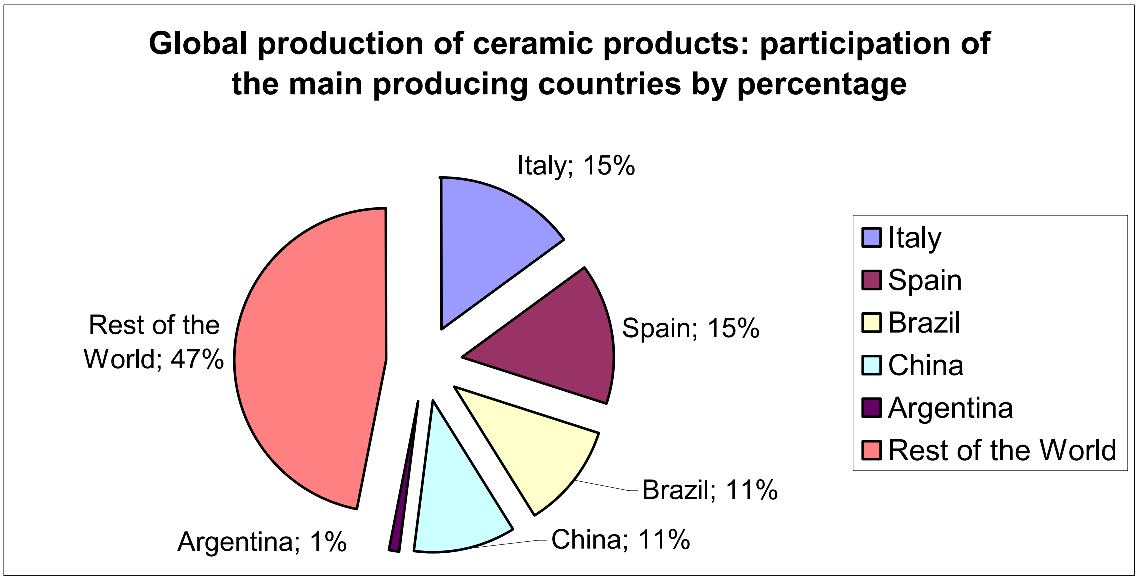


Figure 2.1: Global production of ceramic products

In terms of volume, the main exporting countries of the Mediterranean region are Italy, with a global percentage of 40.8 %, Spain, with 26.4 % and Turkey with 4.7 %. Spain and Italy account for 67.2 % of global exports. Turkey, with 4.7 % and France, with 1.9 %, are among the 20 main countries that export ceramic products.

In terms of the main countries that import ceramic products from Italy in the Mediterranean, France stands out with 14.1 % of the global total of purchases, followed by Greece, which imports 2.9 % of the products exported by Italy.

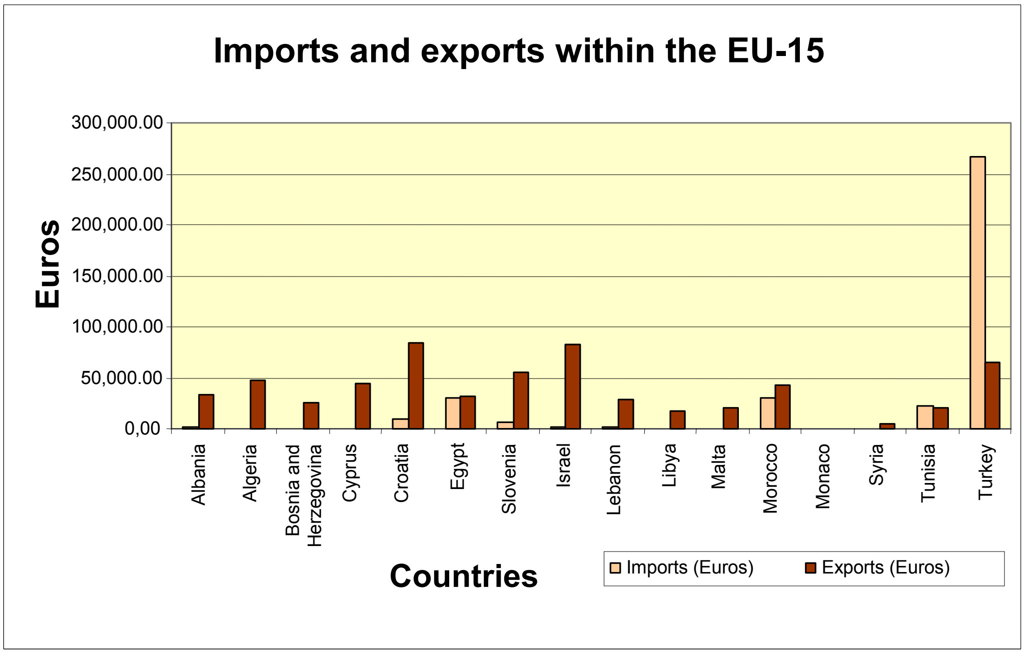


Figure 2.2: Imports and exports of the EU-15 countries

Of the countries of the Mediterranean region, those belonging to the European Union of 15 members stand apart (due to the recent incorporation of the latest countries in 2004, the market with these countries is not yet sufficiently extended) with higher levels of industrialisation in the structural ceramics sector, together with a larger market among the countries of the group. The imports and exports of these countries to and from other Mediterranean countries can be seen in the following graphs.

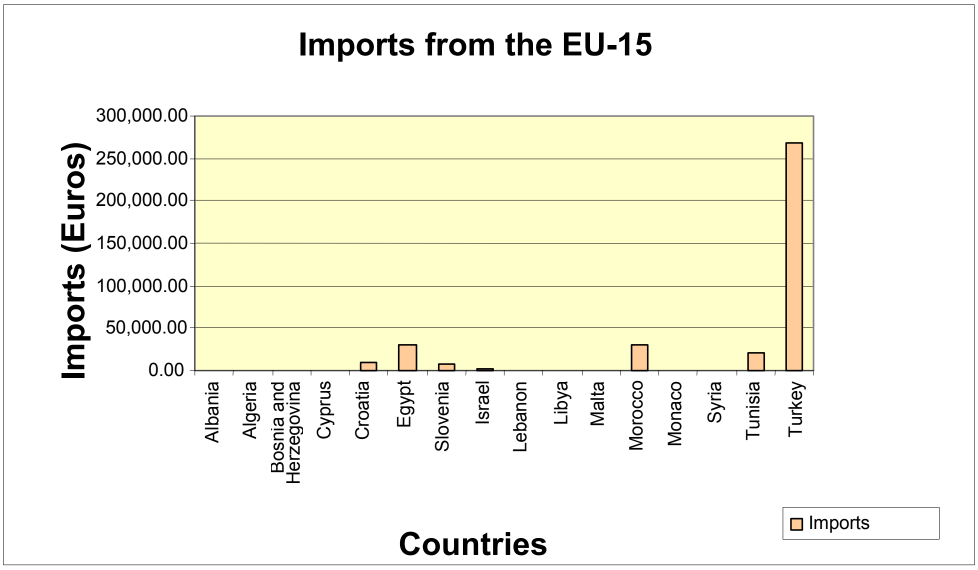


Figure 2.3: Imports from the EU-15 countries

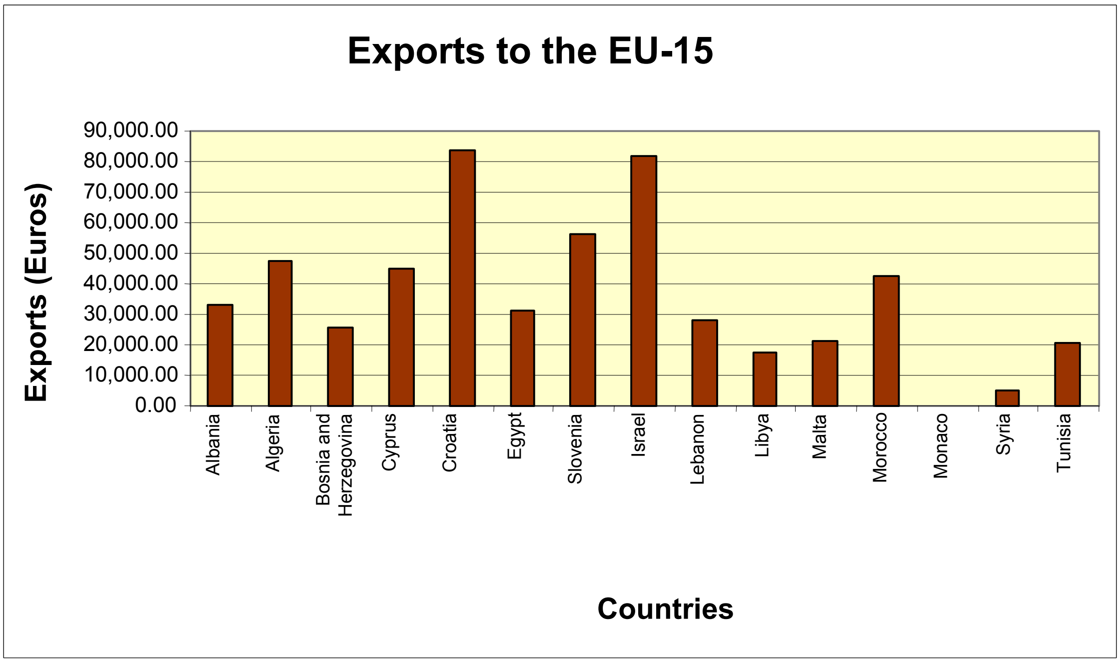


Figure 2.4: Exports to the EU-15 countries

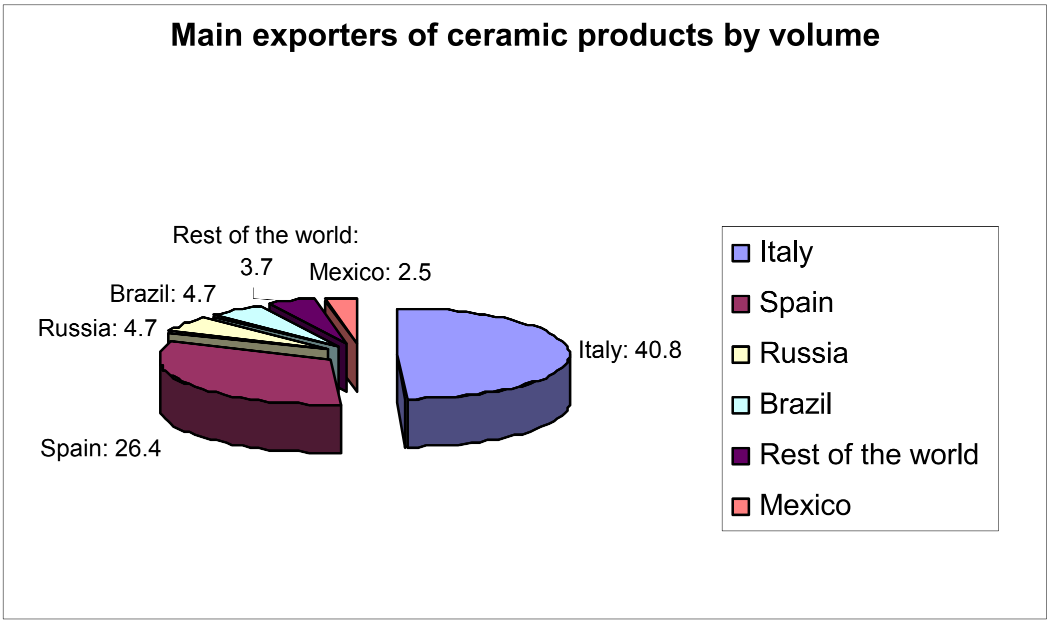


Figure 2.5: Main exporters of ceramic products by volume

It can be seen that the imports of these countries are far lower than their exports. This fact is essentially due to the greater purchasing power of the countries of the European Union, which results in more construction activity, and therefore greater demand among these countries for ceramic products.

The following graph details the exports of the Mediterranean region countries, showing Italy as the main exporting country, followed by Spain, the two making up 57 % of the total.

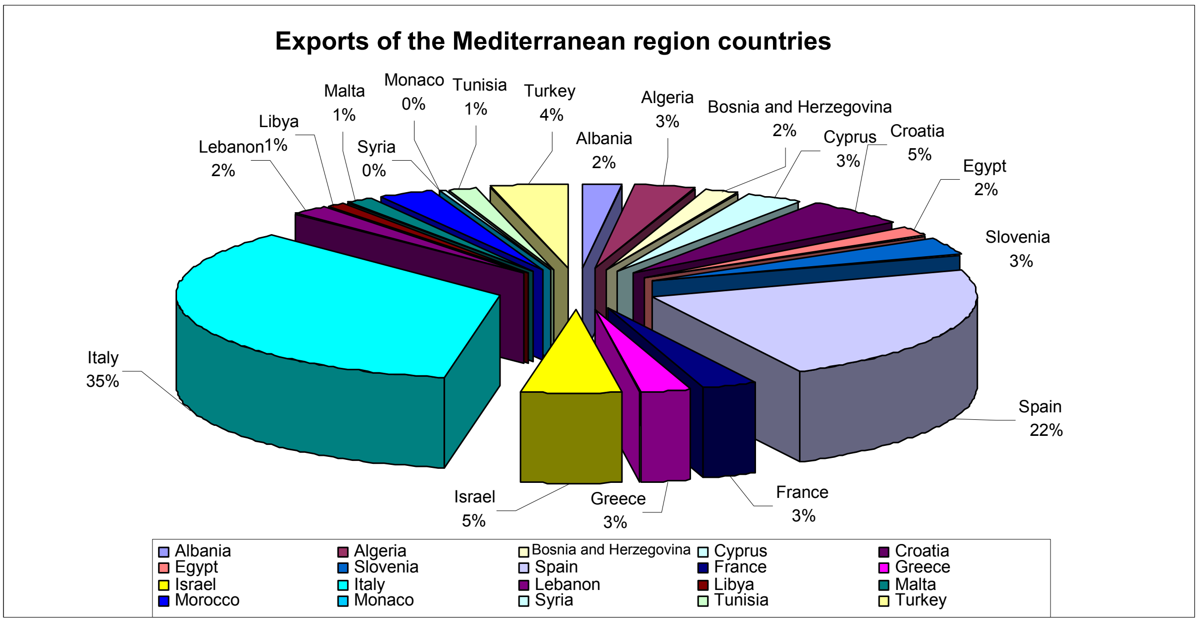


Figure 2.6: Exports of the Mediterranean region countries

2.1.1. Albania

Albania has a population of over 3 400 000 inhabitants, of which 65 % live in agricultural zones and the remainder live in cities. By way of general information, the fact that 79 % of Albanian companies have 1 employee and 52 % of companies are classified as being within the trade sector can be highlighted. On the other hand, 10 % of companies fall within the industrial sector and are concentrated particularly in Tirana, Durres and the Elbasan corridor.

Construction, in addition to agriculture (Albania is a country in transition in which agriculture still provides over half of GNP) is the most dynamic sector in the country's economy, with an annual growth rate of over 11 %.

There is a clear need for the development of infrastructures and transport, and therefore the ceramics sector within the country, or failing that, the import of these products from other countries, is forecast to increase in coming years, as in terms of industrial production, Albania has an important competitive advantage over other countries in the Mediterranean, due to low wage costs.

2.1.2. Algeria

The construction sector and public works make up 10.8 % of the economy, which consisted of a GDP of 299.4 million Algerian dinars in recent years.

Algeria has an important industrial framework consisting of 150 public companies that in recent years have been grouped into holdings, and for which there are plans for future privatisation, as many public companies are producing at levels below their capacity. The ceramics sector stands out within the country's light industry.

The construction sector, which is the main consumer of structural ceramics products manufactured, is heavily indebted to the banking sector.

The country has a major housing shortage, and there are also great needs in the area of transport and water distribution infrastructures.

The main companies in the construction sector form part of the BMC public holding company. These consist of 12 cement manufacturing companies, 3 brick manufacturing companies with 34 production units, and 2 companies manufacturing ceramic products and bathroom fittings.

The companies in the ceramics sector are undergoing a process of privatisation. In 2001, construction materials represented 8.2 % of activity in the Algerian private sector.

As part of its programme, the Algerian Government intends to foster the construction of housing in coming years, and as a result, increased consumption of construction products and therefore structural ceramic products is anticipated.

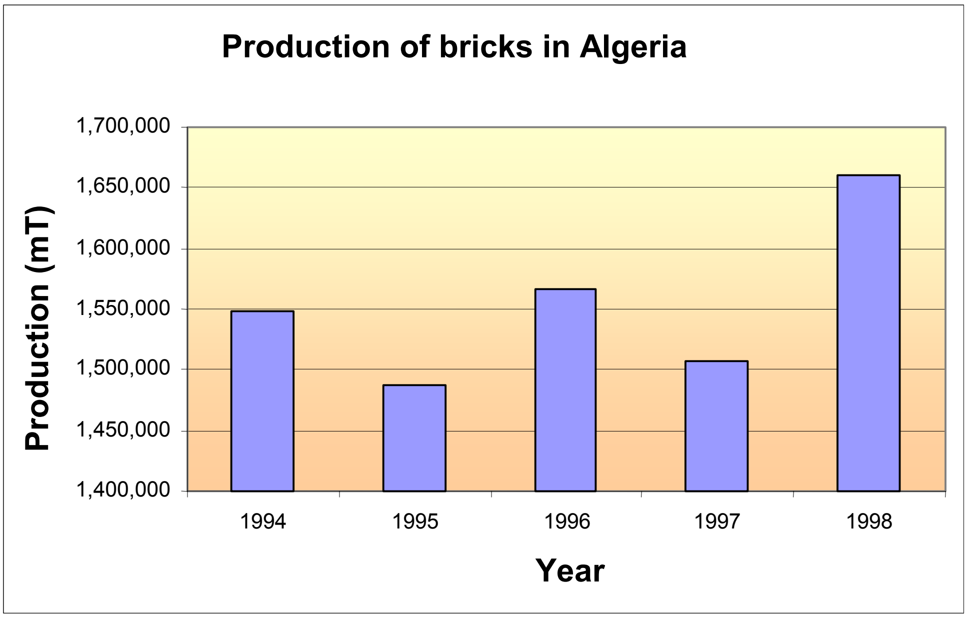


Figure 2.7: Production of bricks in Algeria

2.1.3. Bosnia and Herzegovina

Before the war (1992-1995), Bosnia and Herzegovina had a relatively developed and important industrial base. Industrial activity was concentrated in 10-15 major state-owned conglomerates which provided over 35 % of GDP, while the remaining companies were small in size. Today, some of these conglomerates have signed joint venture agreements with foreign companies.

Little progress has been made in the deregulation of companies and the introduction of a genuine market economy. The greatest advances have taken place in the Federation of Bosnia and Herzegovina.

The main problems facing the industry are, in addition to its physical destruction, its obsolete capacity, the lack of capital, the destruction of its channels of distribution and the loss of its markets. The government is also faced with the problem of the large state-owned conglomerates and the important pressure groups demanding their recovery in order to avoid massive job losses. Despite this, the trend is for the division of these large companies into smaller units.

After the war, the construction sector, and therefore the structural ceramics industry, experienced significant growth due to the necessary rebuilding of those areas devastated by this war.

At present, there are 22 major manufacturers of construction materials that coexist with a large number of building construction companies, all of which are small and privately owned.

Bosnia and Herzegovina still has no well-structured business sector and associations within the private sector may take time to organise, at least until such times as the majority of public companies have been privatised. This means that as yet, associations specific to the structural ceramics sector have not been formed.

This does not mean that private businesspeople are not in contact among themselves to take joint action when facing the government in order to attain the best possible conditions for each of their particular markets.

As for exports, the structural ceramics sector is made up of companies capable of meeting local demand, but which have limited potential for export.

2.1.4. Croatia

The difficult transition to a market economy, the outbreak of the conflict in the former Yugoslavia and the loss of its external markets sank the Croatian economy into a crisis from which it began to emerge at the end of 1993. By 1998, the economy had recovered, thanks to economic growth fostered by the success of the Stabilisation Plan (October 1994), peace being achieved (November 1995) and a programme of economic and legislative reforms. Following the 1999 recession, which affected the industrial sector above all, and the economic adjustment of 2000, there are good possibilities for short- and medium-term economic growth, due above all to increased investment.

Since independence, one of the main objectives of the economic policy programme has been the privatisation of state companies.

The construction sector is of major importance to the Croatian economy. It generates 5.9 % of GDP and at the end of 2003 provided employment for 77 300 people. It has been showing signs of recovery since 2001 thanks to the country's improved economic situation, funds from the EU and multilateral financial bodies and the entry into the country’s economy of foreign currency from tourism. In addition to construction in Croatia, the sector also participates in projects and works in other countries. These countries include Bosnia and Herzegovina, Russia, Germany and some Middle Eastern and North African countries.

2.1.5. Cyprus

In Cyprus, the construction sector provides around 7 % of GDP and 9 % of total employment in the country.

Following the division of the island in 1983, dividing it into the northern part (Turkish-held Cyprus) and the south (Greek-held Cyprus), the construction sector underwent considerable growth due both to the construction by the government of housing for refugees and to infrastructure projects involving the construction of new airports and ports.

Later, towards the end of the 1980s, the sector experienced a second period of growth as a result of the construction of new hotels and restaurants. For this reason, the consumption of products from the structural ceramics sector increased considerably.

The sector has increased its activity during this decade. From 2001, construction began to recover significantly due to the interest of both the country's own population and interest from abroad in the purchase of property, including holiday homes and governmental infrastructure projects.

During 2003, the total number of new licences increased by 14.8 % and the total value of construction went up by 17.1 %. Growth was concentrated in the residential sector.

Due to demand from the Cypriot and foreign population (it should be remembered that one of the sectors that provides most income for the island is the tourist industry) the number of licences granted increased by 47.1 % during 2003.

At present, construction activity would appear to be falling off somewhat, although there are no exact statistics available to demonstrate this.

2.1.6. Egypt

Egyptian industry has traditionally been dominated by the public sector, which has left a legacy of low productivity and insufficient use of production capacity, together with inflated workforces. However, since the introduction of liberalising measures in 1991 and a programme of privatisations in 1996, private investment has been gaining more weight.

However, state-owned companies still represent 40 % of industrial production and around 80 % of exports of industrial products. They also employ 55 % of the workforce. Despite the Government's fostering of industrial projects, the industrial private sector is faced with a restrictive regulatory framework. Private activity is concentrated in construction, among other areas.

The structural ceramics sector is classified within the small-scale industrial sector with regard to the country's economy. The majority of industrial activity is concentrated around Cairo and Alexandria.

2.1.7. France

The industrial sector in France is at the forefront of technology. In the construction and public works sector, France has an important framework of companies of all sizes. The level of internationalisation of French companies is also notable, as they have large numbers of branches abroad. Nevertheless, there are still numerous small, family-run companies in France.

With regard to the public sector, there is a continuing privatisation process of the public industries.

The production, sales and investments of the construction sector are outlined in the table below. It can be seen that in this sector, investment is very high with respect to sales: 70 % for construction and 82 % for public works.

Table 2.2: Situation of the construction sector in France

	CONSTRUCTION	PUBLIC WORKS
Ventes	147.8	39.43
Investissements	103.72	32.38
Consommations intermédiaires	35.08	7.05

In billions of €

Source: Tableaux de l'économie française 2003-2004

The construction of dwellings has evolved as shown:

Table 2.3: Evolution of the number of dwellings

YEAR	NO. DWELLINGS
2001	302,243
2002	302,689
2003	314;364

In residential construction, the evolution of dwellings begun showed an increase of 9 % at the end of 2003, the highest since 1998, following decreases in 2000 and 2001 and a level that was barely maintained in 2002. This figure is very similar to the 1999 figure, the year with the highest number of dwellings in the last decade. This sort of number of licences involves an area of almost 42 million m2, 8.9 % more than in 2002. This growth was based mainly on collective dwellings (of two or more), which increased by 10.5 %.

If the import figures have not increased by the same proportion, this could be due to the fact that there is a time lapse between the granting of the licence and the construction of the building in question, which may be up to several months.

While until 1994, collective dwellings represented the largest part of new construction; from 1995 the tendency was reversed, to the point that today, individual dwellings represent 65 % of the total.

This positive evolution has been encouraged above all by a government policy providing tax relief.

With the exception of the year 2000, due to the violent storms that battered France, new construction accounts for 52 % of the market value, ahead of renovation work, which makes up the remaining 48 %.

The following graphs show the evolution of licences granted and begun since 1999, together with data on the area granted and the area that was in fact created.

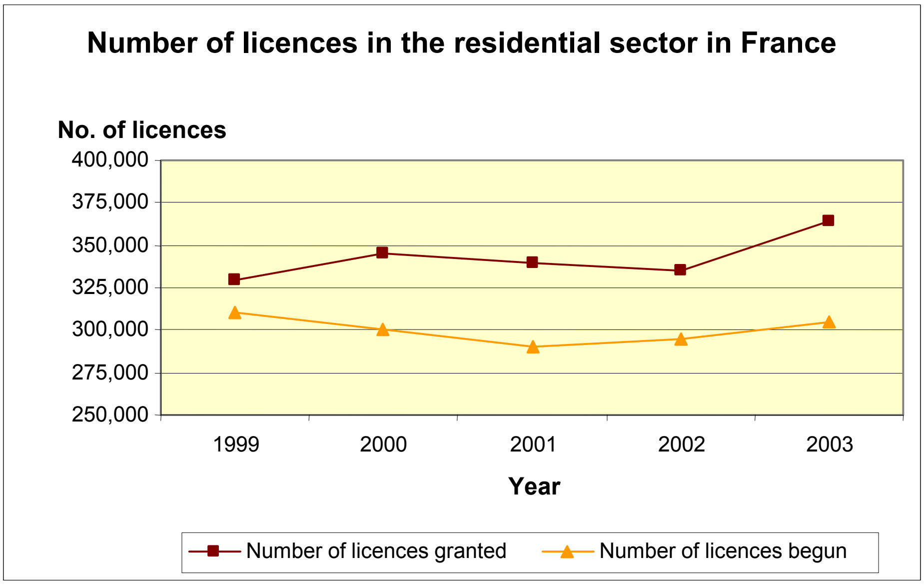


Figure 2.8: Evolution of the number of licences in the residential sector in France

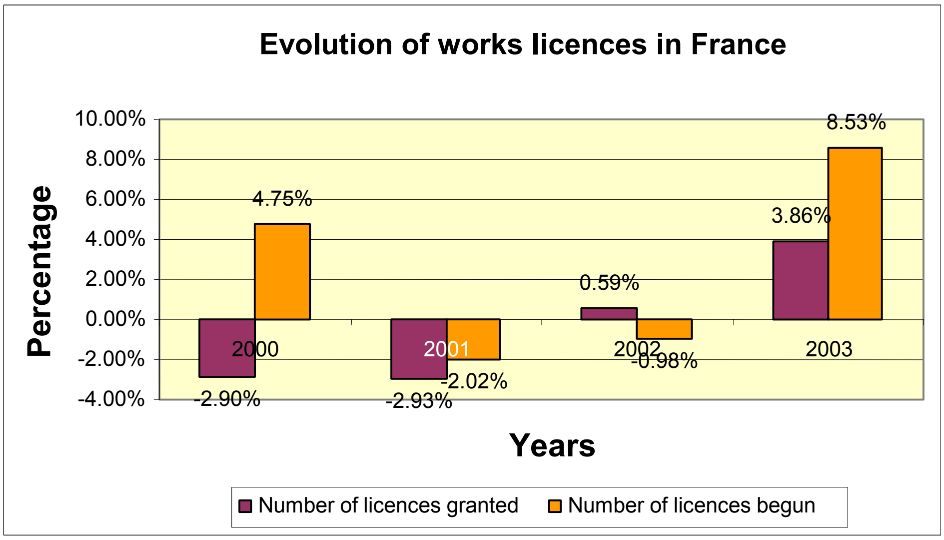


Figure 2.9: Evolution of the number of licences granted and begun in the residential sector

The average area of dwellings remained generally stable and only increased for individual dwellings.

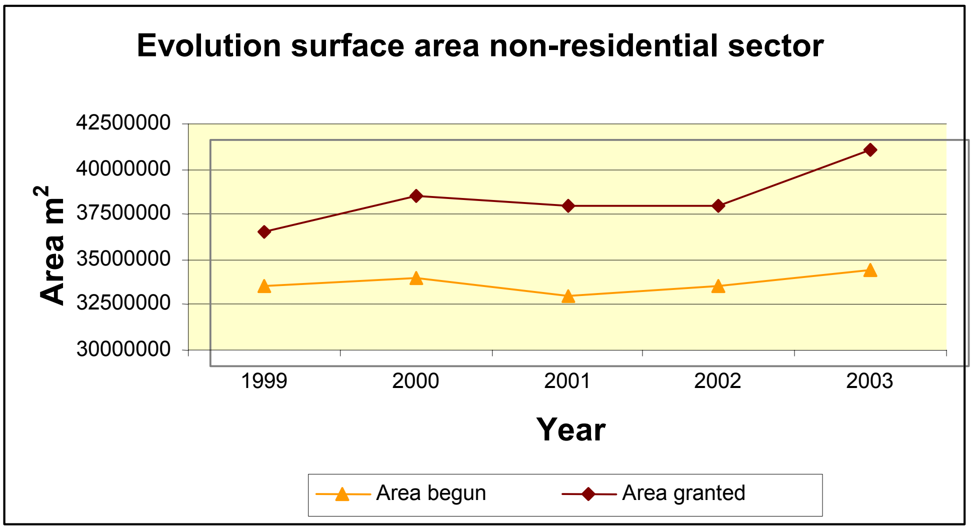


Figure 2.10: Evolution of constructed area authorised and begun in m^2

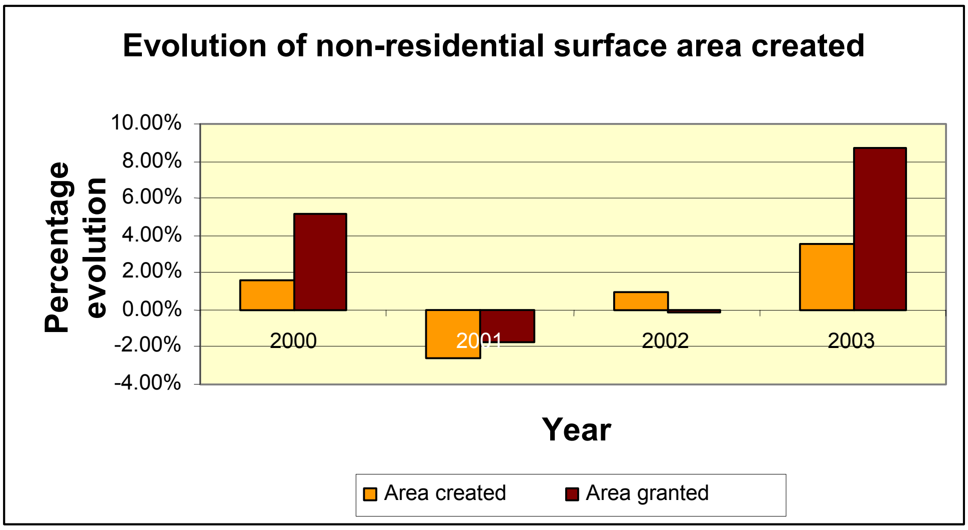


Figure 2.11: Evolution of the non-residential area created and authorised in percentages with respect to the previous year

Lastly, and according to data from the French Federation of Construction, there are different factors working in favour of the construction sector:

1. **The need for housing:** according to the latest estimates from the INSEE (French National Institute for Statistics and Economic Studies), for over 20 years, the number of dwellings constructed has been lower than the real figure required.

2. **The need for maintenance, renovation and reconstruction of buildings:** both social housing and rented housing are deteriorating.

3. **The need to equip business sectors:** company needs are high, as the majority (between 50 % and 80 %) contract professionals to carry out their maintenance work.

2.1.8. Greece

One of the most notable aspects of the Greek economy is the importance of construction in terms of its contribution to total added value.

Construction has contributed 7.5 % to total added value, and has meant significant growth in recent years.

The construction sector is currently benefiting from a favourable economic climate. The celebration of the Athens Olympic Games in 2004 promoted the consumption of construction materials, which included a significant proportion of structural ceramic products.

Greece is a country in which the structural ceramics sector is dominated by imports and where it is forecast that demand will increase in the future.

2.1.9. Israel

The industrial sector as a whole (including construction) accounts for 31 % of the country's economy. Although traditionally the government and the trade unions played a fundamental role in its development, the situation is very different today and the economy is fairly liberalised.

Small and medium-sized enterprises, which account for 37 % of production, are of major importance. The focus on technological research and development is also notable, with a relative spending level that is among the highest in the world.

The ceramics market is particularly important in Israel, with imports of €68,816 M and exports at the much lower level of €1,053 M. This makes the country mainly a consumer of these products, as it cannot meet its requirements with its own production levels.

2.1.10. Italy

The balance sheet of the Italian economy in recent years shows growth in construction, although this growth has been slowing gradually since the year 2000.

According to figures provided by the Italian National Association of Constructors (ANCE) investment in the construction industry reached 107.4 billion euros, an increase of 6.3 % with respect to the previous year.

With regard to residential construction, according to figures from the same association, investments in residential construction reached a level of 58.433 billion euros during 2002. In comparison with previous years, there was an increase of 6.7 % in terms of value (including inflation) and 2.5 % in quantity (0.9 % according to Istat) due to the positive dynamics experienced in the construction of dwellings, together with the revaluing of property. On the other hand, the demand for social housing underwent a notable decrease, while private construction increased. Therefore, according to figures from the Italian Central Bank (Banca de Italia), loans generated for the purchase of dwellings increased from 29.2 billion euros in 2001 to 36.9 billion euros in 2002 (an increase of 26.4 %), while those generated for the renovation and restoration of dwellings increased from 15.1 billion euros in 2001 to 16.3 billion euros in 2002.

Table 2.4: Evolution of the construction sector

YEAR	Residential construction			Non-residential construction				
	New construction		Extensions	New construction		Extensions	Dwellings	
	No.	Volume	Volume	No.	Volume	Volume	Total	No. for residential construction
1996	35,348	65,946	10,588	20,884	81,430	31,191	155,078	150,276
1997	32,212	60,536	9,668	17,726	63,887	27,096	144,597	140,528
1998	28,455	56,268.5	9,220	16,613	67,444	29,864	136,650	132,890
1999	29,705	62,080	9,434	17,089	81,616	33,718	151,652	147,397
2000	33,065	67,126	9,263	17,185	94,165	31,552	162,407	158,442
2001	32,435	68,735	8,683	16,787	100,652	33,700	167,541	163,542

Source: ISTAT

The annual growth rate of construction shows a progressive decrease in recent years.

Table 2.5: Annual growth rate of construction in Italy

ANNUAL GROWTH RATE OF CONSTRUCTION IN ITALY						
	1999	2000	2001	2002	2003	2004
Annual growth rate	5,1	5,6	4,8	1,6	-0,3	-1,2

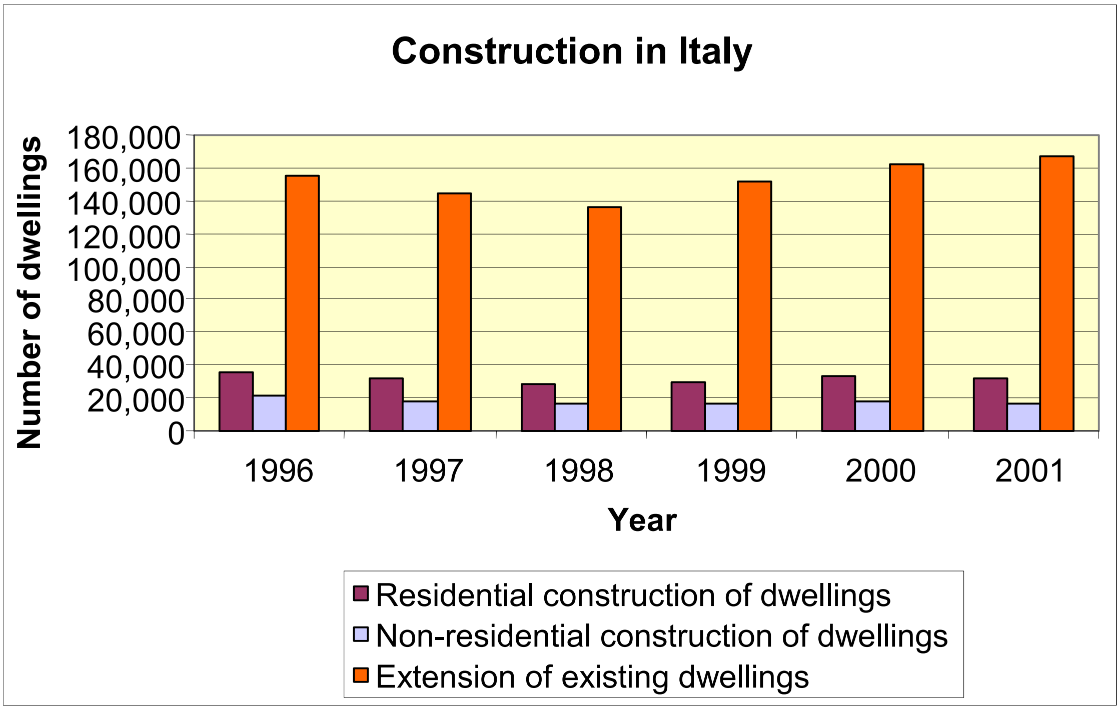


Figure 2.12: Evolution of dwellings of residential construction, non-residential construction and extended

Italy is the main global producer of ceramics, with a share of total production reaching 15.3 %. This level, although significant, has decreased slightly, with Italy's quota of global production decreasing from the 1995 level to 15.3 % in the year 2000. Nevertheless, the volume of production has continued to increase.

At present, the sector is undergoing a process of concentration, with the number of companies decreasing due to mergers, acquisitions and agreements.

According to the latest statistics, the main exporting country by volume is Italy, with a global market share of 40.8 %. Taken together with Spain, the two countries account for 67.2 % of global exports.

Italy's participation in global trade has decreased slightly (from 45.7 % in 1994 to 40.8 % in 1999) despite the fact that its exports grew significantly (from 324 million m^2 in 1994 to 416 million in 1999).

Table 2.6: Italian exports of ceramic products (in millions of euros)

DESTINATION COUNTRY	1998	1999	2000	2001	PARTICIPATION IN 2001
Germany	651	589	511	463	16.6 %
United States	349	410	478	462	18 %
France	377	374	358	364	14.1 %
United Kingdom	71	70	69	82	3.1 %
Austria	103	93	83	79	3 %
Greece	89	79	74	76	2.9 %
Switzerland	68	69	64	70	2.7 %
Netherlands	68	65	60	61	2.3 %
Poland	78	76	71	61	2.3 %
Australia	69	64	61	42	1.6 %
Rest of the World	875	786	788	972	33.4 %
Total	**2,800**	**2,677**	**2,598**	**2,565**	**100 %**

Source: Export.Ar Foundation report

Total sales in the Italian ceramics sector have decreased due to the drop in sales within the country itself, with an 11.4 % loss of internal market.

Table 2.7: Sales in the sector

	2003	2002	VAR. %
Number of companies	173	173	0
Total sales (mill. €)	1,402.4	1,452.5	-3.4%
Sales in Italy (mill. €)	428.5	484.0	-11.5%
% sales in Italy of total sales	30.6%	33,3%	____
Sales abroad (mill. €)	974.0	968.5	+0.6%
% sales abroad of total sales	69.4%	66.7%	____

In 2002, total production increased by 3.5 %, reaching 18.7 million tonnes.

Analysing the detailed evolution of structural ceramics products in depth, an increase can be seen in the use of brick materials for bricklaying and construction, along with the production of hollow bricks for partition walls, which has grown by 3.1 % in recent years, recovering market share from other types of material, such as plasterboard. A considerable increase was also recorded in the production of forged materials, with 9.67 %.

On the other hand, the production of cladding tiles decreased by 9.4 %, with production dropping to 600 thousand tonnes.

Another segment showing stable behaviour is that of covering materials, which experienced overall growth of just 0.08 %.

2.1.11. Lebanon

The 1975-1991 civil war caused serious damage to industry and trade. After it was over, the central government promoted the renewal of activity. Economic recovery took place to a great extent thanks to small and medium-sized enterprises. The government hopes that reconstruction will provide a motor for wider recovery.

The economy and markets of Lebanon are represented mainly by the private sector, which contributes to around 75 % of overall demand.

Before the conflict, the construction sector had always been important, with a substantial proportion of its activity concentrated in Beirut, where the need for housing for the city's growing urban population had to be met.

Since the conflict in Lebanon, there has been another significant increase in construction. Construction projects are financed mainly by equity participation. This sector has experienced huge growth since 1991.

The mountain cities and towns near Beirut also require materials for construction to meet the demand resulting from increasing tourist activity.

Industry and trade in structural ceramics play a prominent role in general industrial production, with ceramics exports of €5,152,859 and imports of €46,429,889.

2.1.12. Libya

The Libyan economy is dominated by the hydrocarbons sector, which contributes between 20 % and 25 % of GDP, 50 % of public income and between 90 % and 95 % of income from exports. The other important sector is construction (public works and housing).

The public sector has a lot of weight in all areas of production, although the authorities wish to reduce this and to encourage private companies and cooperatives.

As the Libyan economy is based on income from oil, the sharp drop in oil prices in 1998 had a noticeable effect on the country's economic development.

Nevertheless, the construction sector, which contributes 20 % of GDP, has expanded, together with those sectors that provide it with materials, including the ceramics sector.

2.1.13. Malta

The Maltese economy focuses mainly on tourism, agriculture and the service industry, with the European Union as its main trading partner.

With a population of almost 400 000, Malta has a limited internal market and limited production. As a balance to this, the geographical location of the island means that it is in a strategic position for foreign trade.

The competitive advantage of Malta as an exporter is due not only to the proximity of major markets, but also to its good reputation of quality production, confidence and low employment and operating costs in comparison to western European levels.

The re-exportation of products accounts for 10 % of Malta’s total exports.

There is very little production of structural ceramics.

2.1.14. Monaco

Monaco, located on the coast of the French Mediterranean, is a popular destination. Its economy is based on the tourism sector.

The Principality has successfully diversified into the services sector and the small, high added value and non-polluting industry sector. The structural ceramics industry is non-existent in Monaco, which means that the ceramic materials required for construction are imported from other countries, mainly from the Mediterranean.

2.1.15. Morocco

Morocco has a relatively small industrial sector which represents some 30 % of GDP.

The construction and public works sector is important for the workforce that it employs. Its contribution to GDP is 4.9 %.

The structural ceramics sector accounts for a very small part of the industrial sector. It should be noted that the production of ceramics in Morocco is consumed almost in its entirety within the country itself, and there is a need to import ceramic products to meet the country’s internal demand.

In the first months of 2005, Morocco carried out a programme of protectionist intervention in the ceramics sector with the aim of protecting the internal market from the imports that it brings in. Morocco’s main imports come from Spain (60 %), with Spanish imports being of higher quality and therefore selling for higher prices than Moroccan products, which means that they are not in competition with products manufactured in Morocco.

Nevertheless, increased imports from China and the low prices at which ceramic products are sold could represent new competition for local companies.

2.1.16. Slovenia

The Slovenian industrial sector is in general well developed. It is geographically concentrated to the north of Ljubljana. Many Slovenian industries have been operating for over 100 years. In post-war Yugoslavia, Slovenian industry found a market that was open to all kinds of products, and “socialised” companies were created, on occasion ignoring profitability or cost-effectiveness criteria.

Following Slovenia gaining independence in 1991, many particularly costly companies were dismantled or closed when the internal market collapsed; however, the process of adaptation of Slovenian industry to the market is not yet complete.

With an internal market of only 2 million people, the majority of companies are obliged to export a high proportion of the products they manufacture, and to sell components to other Slovenian companies, which leaves the country vulnerable to the economic situation within the European Union, the main market for the products it exports.

Construction, the main target market of the structural ceramics sector, was a priority during the Communist period. With many years of experience, the sector has acquired significant know-how in both the construction of housing and in industrial works such as nuclear and thermal power stations and in civil engineering. Traditionally, major Slovenian construction firms have participated in international projects in Africa, the Middle East, Eastern Europe and Germany.

The construction sector’s contribution to GDP in 2003 was 5.7 %.

2.1.17. Spain

In Spain, the sector is characterised by a high number of family companies dispersed throughout the country.

Recent years have seen an increase in both the number of companies in the sector, which is now over 400, and the number of jobs in the sector, with a figure of around 10 500 throughout Spanish territory as a whole. All of this reflects the growth that is taking place in industry in general.

The concentration of companies in the sector and the opening of major production centres to supply larger areas are hampered by the strong influence of transport costs on the final price.

At present, the majority of production in the structural ceramics industry is intended for regional or national consumption, due to transport costs.

In general, operations are located in the areas near the factories, given that the low value of raw material does not allow for its transportation to be economical enough to be an option.

The main provinces manufacturing this type of product are Toledo (16 %), Barcelona (9 %) and Valencia (8 %), which produce over 2Mt per year and Alicante (6 %), Jaén (5 %) and La Rioja (5 %), which produce over 1Mt each year. The geological formations suitable for exploitation for this use are very varied, ranging from the red clays of the Triassic period to the marled clay of the marine Tertiary period in the Guadalquivir depression.

Spain consumes around 33Mt of clay per year in the production of bricks and roofing tiles (including extruded stoneware paving slabs) with a pithead value of some €82M.

One third of the national production of red clays for this purpose is concentrated on the Mediterranean coastline (Gerona-Alicante), and almost another third comes from the central region (Madrid, Castilla-La Mancha, Castilla-León and Aragon).

Production

In 1996 and 1997, annual production declined, due essentially to the closure of obsolete companies. The increase in 1998, and subsequent years until 2001, was due to the opening of new companies with high levels of production, and in the last three years, with the exception of 2003, the level of growth has been much lower, as the number of new companies and plants created has been minimal and the closure of plants with “Hoffmann” type kiln installations has still not taken place.

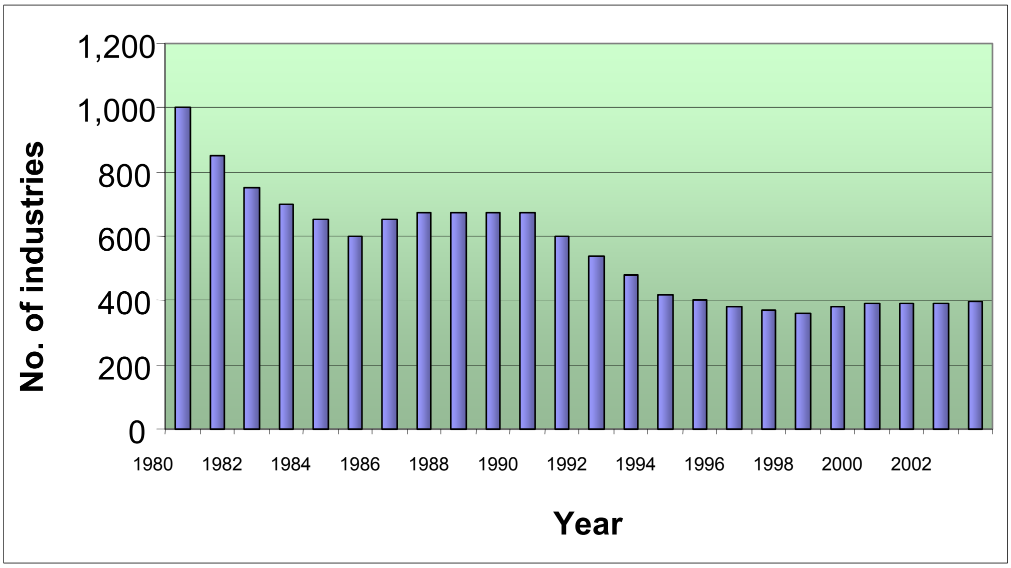


Figure 2.13: Evolution of the number of industries in operation

In 2004, the production of fired clay ceramic materials increased by 1.4 million tonnes, an increase of 5.8 % on the previous year.

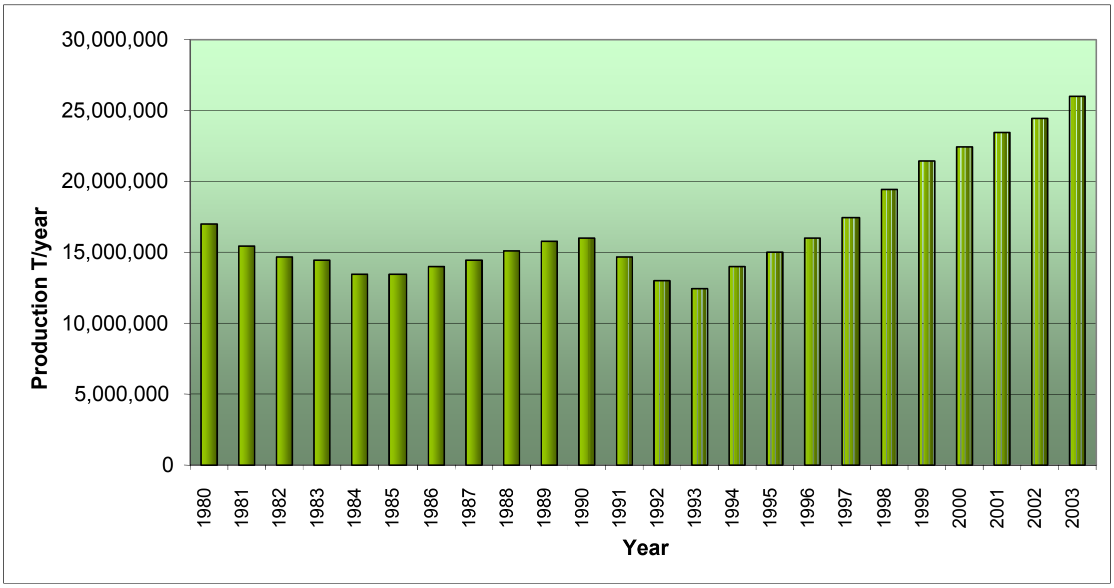


Figure 2.14: Evolution of production

The use of ceramic products (whether bricks, blocks, roof tiles, hollow bricks, setts, lattice tiles or others) continues to increase, due to a great extent to the perception among professionals in the construction sector of the unique qualities of ceramics when applied to structural elements.

It should be mentioned that new installations basically manufacture roof tiles and large-format hollow bricks. During the course of 2003, the sector invested €110M in increasing production capacity in anticipation of the positive evolution in the demand for ceramic products, which was confirmed throughout 2004.

The dependence of the structural ceramics sector on the number of dwellings constructed can easily be observed by comparing the data for housing construction.

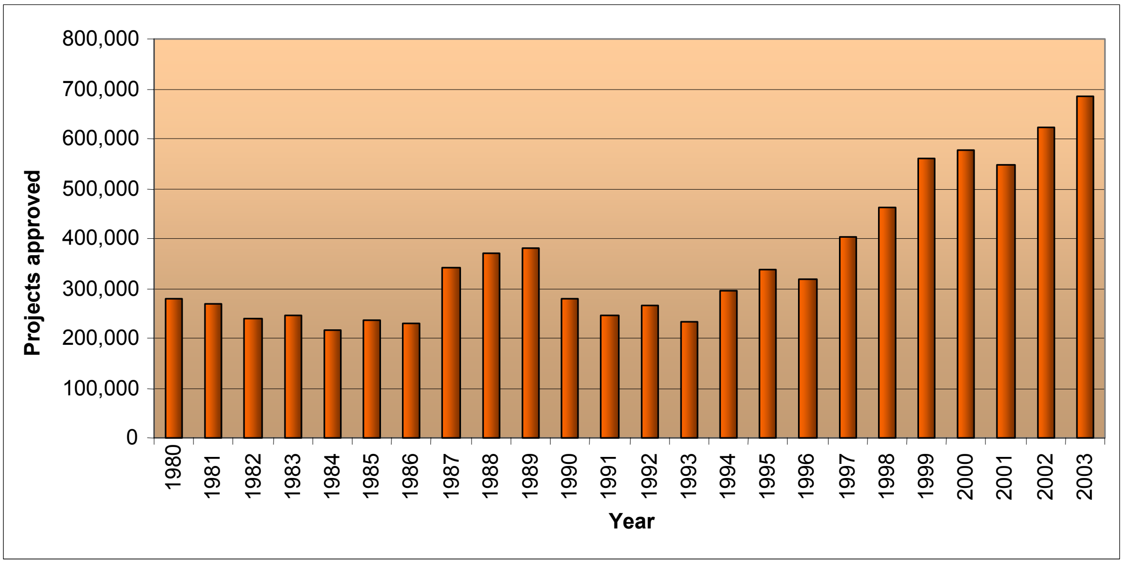


Figure 2.15: Evolution of the number of projects approved

It can be seen from this that projects approved have evolved in parallel with the production of structural ceramics, with the highest growth in the year 2003.

If these figures are compared with dwellings begun, an even greater correspondence can be seen, reflecting the continuous growth from 1994 onwards, and greater growth in both the production of structural ceramics and in dwellings begun.

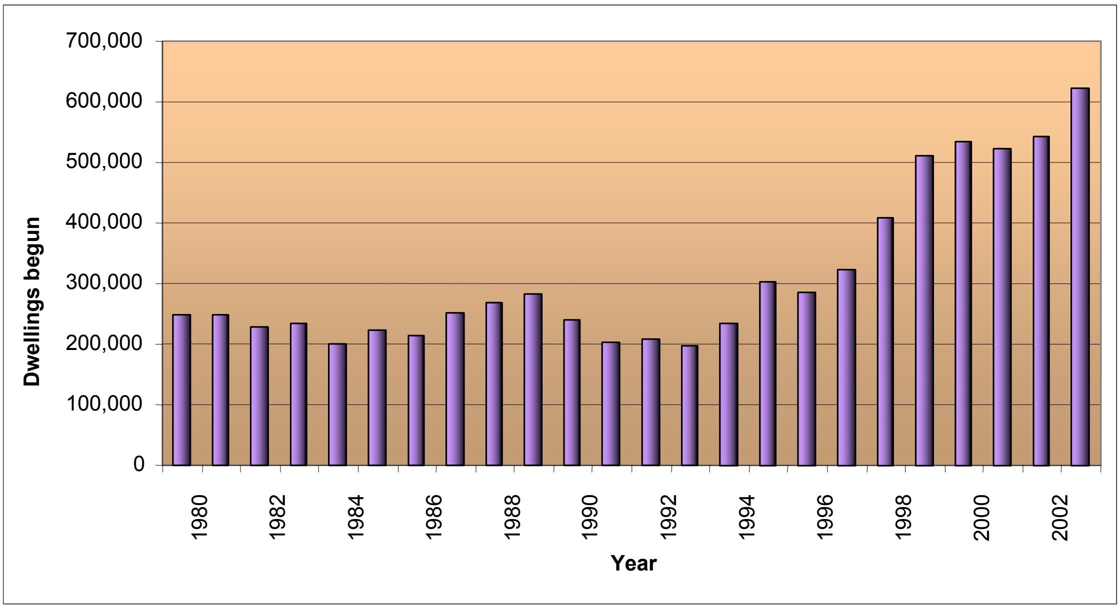


Figure 2.16: Evolution in the number of dwellings begun

As the graph below shows, the number of dwellings completed increases continuously from 1997, with a sharp increase in 2001.

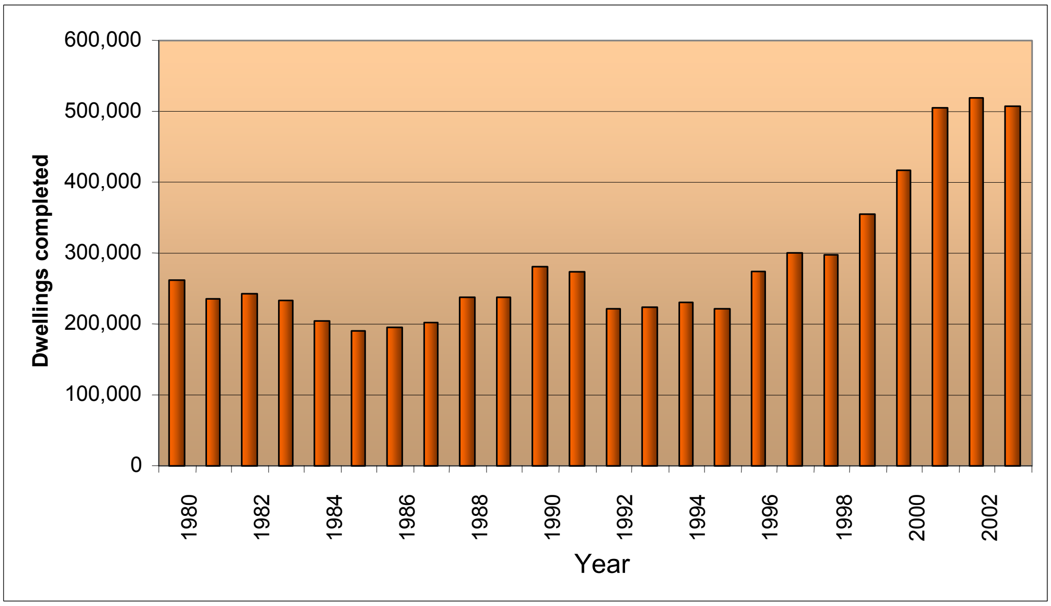


Figure 2.17: Evolution of the number of dwellings completed

Costs

In the costs structure for the Spanish structural ceramics industry, energy costs and personnel costs stand out. As an example, for a factory with a production level of 50 000 t/year, the average cost of production is distributed as follows.

Table 2.8: Costs for a factory with average production of 50 000 t/year

STRUCTURAL CERAMICS	Costs structure
Raw materials	8,35,%
Personnel	32,65%
Electrical energy	10,62%
Heat energy	25,27%
Fuels and lubricants	1,14%
Packaging	6,46%
Maintenance	7,14%
General expenses	4,94%
Technical costs	3,43%

Source: Report from the Ministry of Industry

The current trend is towards the reduction of production costs by means of changes in installations, including the reduction of energy costs and towards the increased use of machinery in processes, which affects personnel costs.

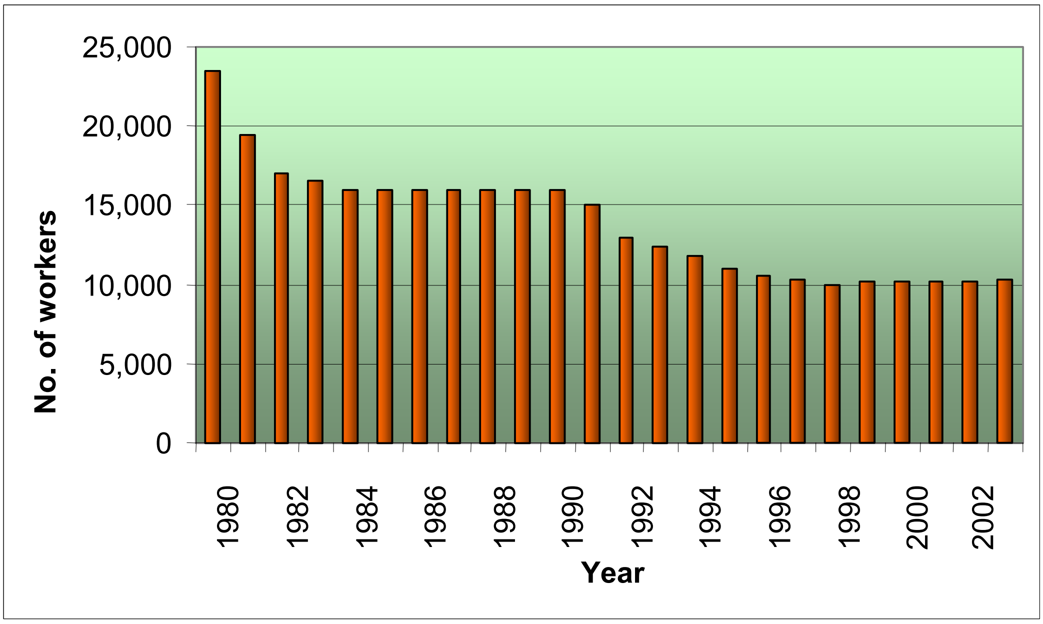


Figure 2.18: Evolution in the number of workers

Associations in Spain

Manufacturers of fired clay ceramic materials are grouped into the Spanish Association of Brick and Tile Manufacturers (Asociación Española de Fabricantes de Ladrillos y Tejas de Arcilla Cocida - HISPALYT). This association was founded in 1968 by a small number of manufacturers who understood the need to join forces to defend the sector's common interests.

Today, HISPALYT brings together almost 225 manufacturers and some 40 associate members (machinery and equipment suppliers, raw materials, laboratory tests, technical advice, consultancy, etc).

The table below provides a summary of data provided by Hispalyt showing the evolution of the most important characteristics of the sector in the period 1980-2003 (data for 2004 is not yet available).

Table 2.9: Evolution of the sector in Spain

Year	Number of workers	Number of industries	Production x 1000 T/year	Dwellings begun	Dwellings completed	Projects passed
1980	23,500	1,000	17,000	250,000	263,000	280,000
1981	19,500	850	15,500	250,000	236,000	270,000
1982	17,000	750	14,700	228,000	243,000	240,000
1983	16,500	700	14,500	233,000	234,000	245,000
1984	16,000	650	13,500	200,000	204,000	215,000
1985	16,000	600	13,500	222,000	191,000	235,000
1986	16,000	650	14,000	215,000	195,000	230,000
1987	16,000	675	14,500	252,000	202,000	340,000
1988	16,000	675	15,100	269,000	239,000	370,000
1989	16,000	675	15,800	283,000	237,000	380,000
1990	16,000	675	16,000	239,000	281,000	280,000
1991	15,000	600	14,700	204,000	273,000	245,000
1992	13,000	540	13,000	210,000	222,000	264,661
1993	12,400	480	12,500	197,000	223,000	234,083
1994	11,800	420	14,000	233,427	229,824	295,027
1995	11,000	400	15,000	302,881	221,718	337,360
1996	10,500	380	16,000	286,832	274,223	319,456
1997	10,300	370	17,500	322,732	299,058	402,076
1998	10,000	360	19,500	407,380	297,928	460,845
1999	10,200	380	21,500	510,637	355,132	561,261
2000	10,200	390	22,500	533,579	415,793	578,385
2001	10,200	390	23,500	523,747	505,173	549,088
2002	10,200	390	24,500	543,060	519,868	622,979
2003	10,250	395	26,000	622,185	506,349	686,278

Source: Hispalyt

2.1.18. Syria

Syria is a developing country with a medium level of income. Despite this, its economy is diversified.

In 1960, due to its socialist state ideology, the government nationalised the majority of important companies and adopted economic policies designed to deal with regional and class inequalities. The remains of this interventionist inheritance are still an obstacle to economic growth, although the government has begun to revise many of these policies, particularly those relating to the country's trading system.

Trade has always been of importance for the Syrian economy, which benefits from its location on trading routes between East and West. In spite of this, the industry of the ceramics sector is not one of the country's main sources of income, with canned foods and modern heavy industry being of greater importance.

2.1.19. Tunisia

In Tunisia, the industrial sector is in general relatively diversified and has grown rapidly over the last decade by between 4.5 % and 10 %.

Tunisian industry, orientated mainly towards exportation, consists of a mixture of numerous family-owned SMEs and large public companies, which are predominant in specific areas such as those relating to construction, including structural ceramics. However, the importance of the public sector has decreased substantially in recent years.

Fostering industrial investment is the responsibility of two specialised public agencies.

2.1.20. Turkey

Turkey is a country with an important industrial base that accounts for 25.6 % of GDP, although the construction sector contributes only 3.6 % of GDP.

This sector has traditionally been important, but the major crisis of recent years has particularly affected it. This has resulted in the construction sector's contribution to current GDP reaching only 3.6 %, due to a reduction in infrastructure projects and in the demand for residential housing.

Construction is one of the important industries in Turkey, with a growing international presence.

The importance of the public sector in strategic sectors of the country's economy is still significant. A fairly ambitious programme of privatisations is currently under development and includes large state-owned companies. Significant advances have been made in this process, although it has been slower than was hoped, with the privatisation of some of the major state-owned companies yet to take place.

2.2. CHARACTERISTICS OF THE SECTOR

2.2.1. Raw materials used

The main raw material used in the manufacturing process of ceramics is clay. A wide variety of different clays are used in the production of structural ceramics, with the differences reflected in their chemical composition. This directly affects the physicochemical properties of the products obtained and the waste emissions, which are generated throughout the process.

Many industries in the sector have their own quarry from which they extract clay of a specific nature. As a result of this they adapt the techniques they use during production in accordance with the composition of the raw material.

As an industrial stone, the most important property of common clay and the property that often determines the possibilities for its use is its plasticity once tempered with water. In addition, the iron, titanium and magnesium contents determine the colour of the fired clay.

Other properties to be borne in mind are the strength of the raw clay, the sintering temperature and the extent to which the clay contracts during drying and firing.

With these characteristics in mind, the three classes of clay that are most commonly used in the manufacture of structural ceramics are kaolinite clays, illite clays and montmorillonite or smectite clays.

2.2.1.1. Kaolinite (white) clays

The size of kaolinite particles is markedly larger than those of other classes of clay. As a result of this grain size, kaolinite clays have somewhat low plasticity, but they dry quickly and without problems due to their greater porosity when dry. This type of porosity is also the cause of their low flexural strength when dry, which usually varies between 10 and 30 kg/m^2.

Where the iron oxide content of the clay is low, the clay is usually of a yellowish white colour after firing, while if it has a high FE_2O_3 content, it is red in colour.

The low content in alkali bases, K_2O and Na_2O, is the reason very high temperatures must be reached during firing. The temperature required can reach 1 200 ºC for this type of clay.

2.2.1.2. Montmorillonite or smectite clays

In general, the use of this type of clay means high moisture levels during moulding, prolonged and problematic drying and high strength when dry.

Montmorillonite or smectite clays generally have a strong tendency to rehydration, a characteristic that makes the elimination of the last moisture during drying more difficult. Moreover, this type of clay has extraordinarily fine grain size (normally in the region of 0.5 microns).

On the other hand, the main advantage of this type of clay is that during firing, it vitrifies at relatively low temperatures (between 800 and 900 ºC) and as a final product, a red-coloured material is obtained that has low porosity and high strength.

2.2.1.3. Illite clays

Illite clay behaves in a way that is midway between kaolinite and montmorillonite clays, and can be classed as the balancing point for the majority of characteristics. In general it provides no drying problems, and its dry flexural strength varies between 40 and 60 kg/cm^2, which means that dry pieces can be manipulated without breakage problems. During firing, this clay is characterised by fairly rapid vitrifying from temperatures above 800 ºC due to its high K_2O content.

Image 2.1: Clay used in the ceramics manufacturing process

2.2.2. Auxiliary materials

It is common practice in some companies in the sector for ground clay to be mixed with different additives, according to the quality requirements for the final product. In general, the most commonly used are:

- Sand
- Barium carbonate
- Calcined clay
- Spent olives
- Micronised limestone
- Polystyrene

In these cases, the products are usually added during the clay grinding process, as in this way the grain size is uniform for the total mixture.

2.2.3. Main fuels used

A wide variety of fuels are used in the different phases of the manufacture of ceramic products throughout the countries of the Mediterranean, depending on a variety of factors, such as price, energy yield, environmental performance, availability, etc.

Section 6 of this manual analyses the chemical characteristics of the fuels, together with the main advantages and disadvantages of using each of the fuels mentioned here.

The most frequently used fuels in the sector are described below.

2.2.3.1. Natural gas

This is one of the fuels that are currently in most general use in the structural ceramics sector in those Mediterranean countries that have the infrastructure necessary for its transportation. Natural gas can be taken from the gas field to where it is to be consumed either through gas pipelines or, in the case of long distances, in a liquid state, using methane carriers or tanker vehicles to carry the gas at very low temperatures.

In the ceramics industry, this fuel is consumed through pipelines, which means that where the necessary infrastructure does not exist, it is very difficult to use natural gas. This is the main drawback of this type of fuel.

In the manufacturing process of ceramic products, natural gas is used in both firing kilns and in dryers.

In general, natural gas burners within kilns are of the vertical type and are divided into two rows of nozzles. These burners are high speed, allowing eddy flows of hot air inside the kiln and therefore achieving both a uniform temperature at different levels within the kiln and the elimination of the danger of breakage in the material at the pre-heating stage.

In addition, as they provide a uniform distribution of heat, this makes them suitable for use in the preparation area, as that is where the most critical point in the firing cycle appears.

2.2.3.2. Petroleum coke

This is a solid by-product of the oil refining process, which is classed as a fuel. Its use as fuel in the ceramics sector is rapidly becoming widespread, due above all to two factors, its price and its energy efficiency. It can be used in firing kilns as the only fuel or it can be mixed with other fuels (usually natural gas, but also with fuel oil), which enables better results to be obtained. It is also used to mix with the clays.

Image 2.2: Ceramics kiln with mixed feed burners of fuel oil and micronised coke

The main producer of petroleum coke is the United States. The consumption of this type of fuel in Spain began some 25 years ago, substituting the consumption of coal. In fact, Spain is the second-largest consumer of petroleum coke in the world after the United States, although its use is increasing in other countries, for example Morocco.

Petroleum coke is also consumed as fuel in other Mediterranean countries such as France, Italy, Morocco, Tunisia etc., as it is commonly used in the manufacture of cement.

Micronised coke

Micronised coke is being developed as part of the search for more efficient fuels for the sector. An industrial grinding process is used to reduce the average particle size, so that 90 % of particles are under 90 microns, giving this type of fuel the following advantages over conventional petroleum coke:

- Moisture is removed from the product (in general under 0.5 %)
- The grain-size distribution is more homogenous, enabling greater control of the kiln
- It has a higher NCV (NET CALORIFIC VALUE)

It has only come into use relatively recently, since approximately the year 2000, and Spain is the only country to use this product in the ceramics sector (approximately 10 %); although, its use is beginning to spread to other countries, as a result of its advantages in comparison to conventional petroleum coke.

2.2.3.3. Fuel oil

This is a thick, dark liquid which is used for industrial kilns and for heating. As its ignition temperature is high, combustion is difficult to maintain, and thus preheating is necessary. When conditions are unsuitable for its combustion, black gases with a high pollutant load are produced.

Fuel oil is the most economic liquid fuel.

The use of fuel oil as a fuel in the ceramics sector is decreasing, due to the difficulty inherent in its use and its low economic efficiency, although there are Mediterranean countries that still use it in their processes.

Fuel oil is normally used in firing kilns.

2.2.3.4. Coal

The most common types of coal in the sector are bituminous coal and semi-anthracite coal. Some countries still use this fuel in kilns during the firing process of the material, although its energy yield and environmental characteristics mean that its use is progressively decreasing.

2.2.3.5. Biomass

This product is in high demand in the sector due to its environmental advantages with respect to fossil fuels, as, for those countries that form part of the framework convention on climate change, it is considered to have zero emissions and is therefore neutral in terms of CO_2 emissions. This has meant the progressive increase in demand for this type of fuel, with the resulting increase in price.

Its high price, together with its intermittent availability, means that it is use in the sector is very irregular.

Its main application is as fuel in dryers, although it is also used for the mixing of clays.

The most widely used types of biomass in the structural ceramics sector in the Mediterranean countries are:

- Spent olives
- Grape marc
- Nutshells

It should also be highlighted that other alternatives related to the use of by-products that could be used directly or mixed with other fuels in the structural ceramics manufacturing process are being studied. Some examples of this are sludges from wastewater treatment plants, urban waste, forestry biomass, etc.

2.2.4. Flow chart

The diagram below shows a flow chart of the manufacturing process of structural ceramic products. The process is in the central part of the diagram, and the inputs and outputs to and from the process are to the left and right, respectively. A detailed description of each of the sections is contained in Section 4 of this manual.

In addition, the associated environmental aspects, such as consumption and environmental impact caused, are also shown.

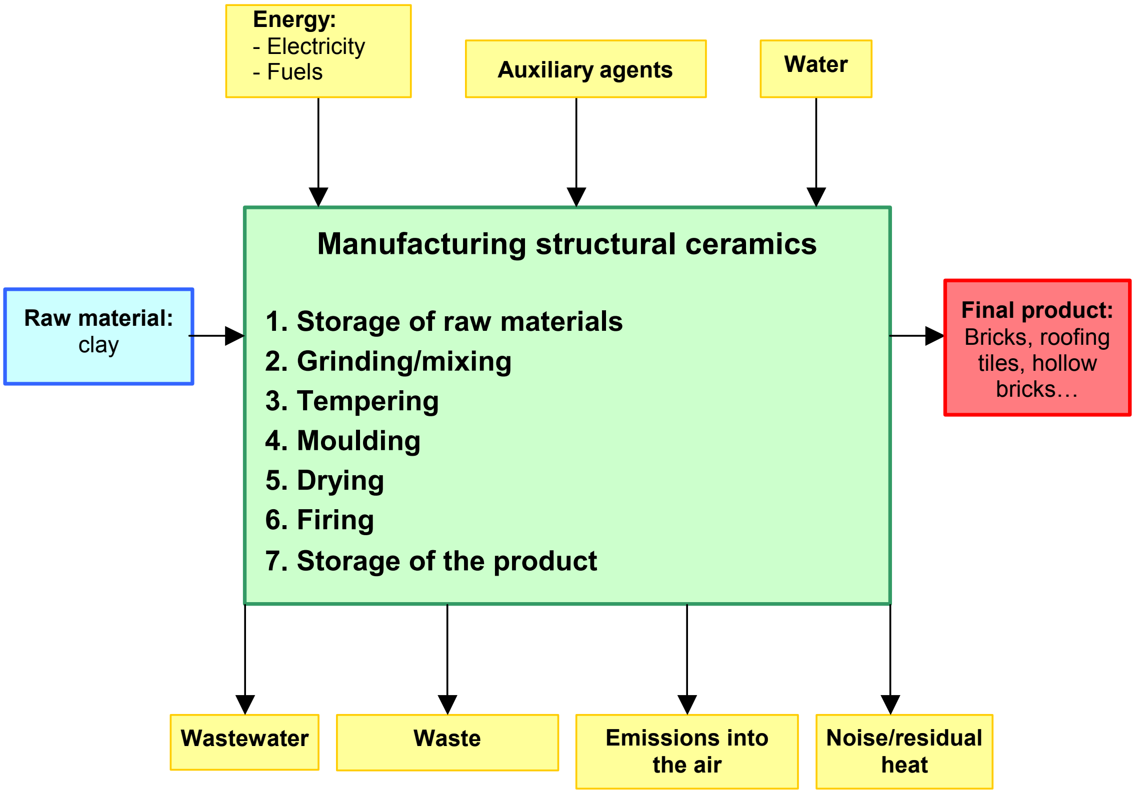


Figure 2.19: Flow chart of the manufacture of ceramic products

3. PHASES IN THE MANUFACTURE OF CERAMIC PRODUCTS

This chapter describes the different production processes in the manufacture of structural ceramics, indicating the technologies used and the related environmental aspects and impacts.

Three different aspects will be analysed in each of the sections:

a. An explanation of the ***process***
b. ***Associated technologies***
c. Flow chart with the inputs and outputs of the process and their ***environmental aspects***.

The general structure of the flow charts provided for each process is:

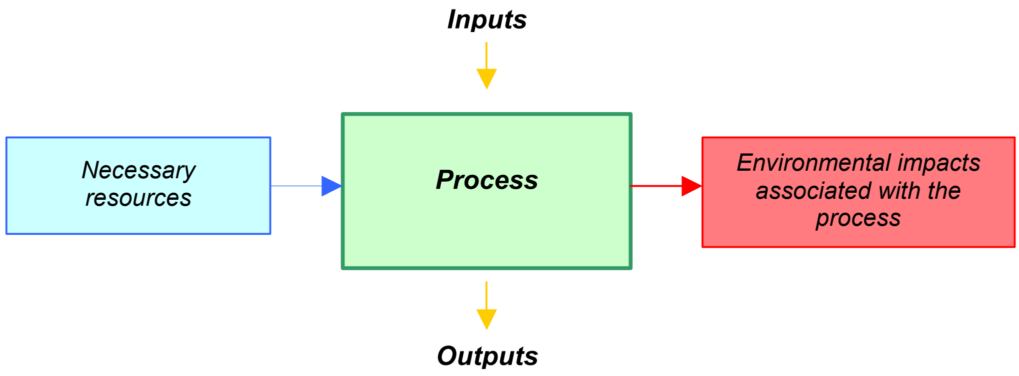


Figure 3.1: General structure of the flow chart for each process

At the end of the chapter is a table summarising the processes described and their environmental impacts. In addition, a qualitative evaluation is made of each one of these, depending on their relative importance in the production process as a whole.

A three-tier method of classification has been established, with levels of importance A, B and C, which signify the following:

Table 3.1: Evaluation criteria of environmental aspects

Level A	Aspect with a very significant environmental impact
Level B	Aspect with a moderate environmental impact
Level C	Aspect with an environmental impact of little significance

This evaluation is intended as a guideline and will need to be examined in each specific case, depending on the technology used by the company and the way that the process is carried out.

These criteria will be maintained for the different evaluations made in this manual.

3.1. GENERAL DIAGRAM

The structural ceramics manufacturing process can be different in each company, depending on the parameters indicated in the above points of this manual. However, the most generalised case is detailed here, indicating each of the processes involved and identifying the environmental impacts associated with each one.

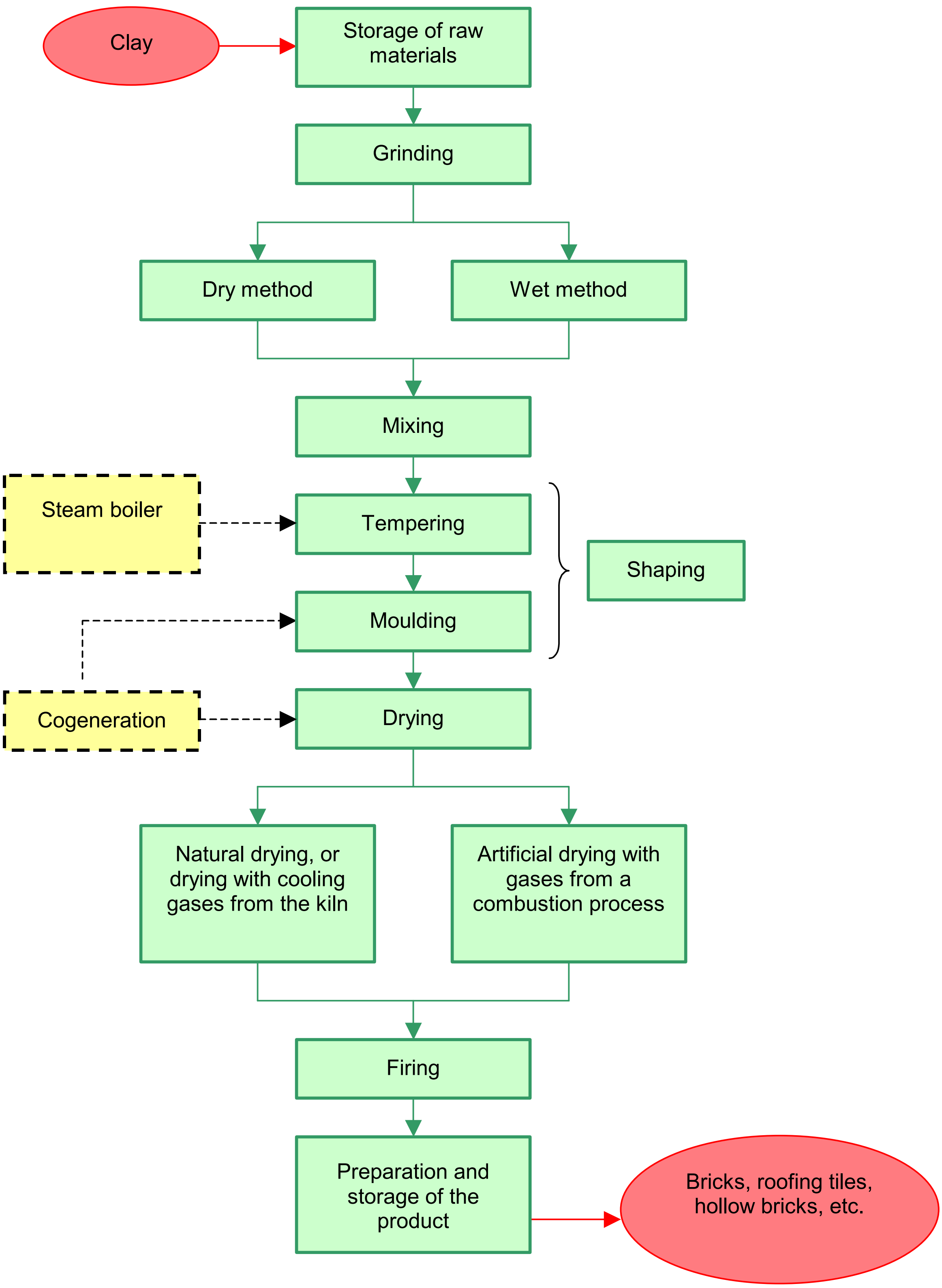


Figure 3.2: Manufacturing processes for structural ceramic materials

3.2. RECEIPT AND STORAGE OF RAW MATERIALS

a. Process

The majority of companies operating in the structural ceramics sector obtain their raw materials from quarries close to their installations, whether these quarries belong to them or to third parties. This untreated clay is transported by truck to the company's site, where it is unloaded and stored for later use.

b. Associated technologies

Storage can be in the open air, in warehouses or in a ***storage hopper***.

A storage hopper consists of a receptacle designed to store the clay that arrives directly from the quarry. It is normally made from anti-wear steel plates and has sufficient capacity to supply the plant for several hours.

Image 3.1: Mixed storage for raw materials in the open air and in a warehouse

c. Environmental aspects

As a result of the manipulation of the dry clay in the loading and unloading of trucks and in the filling of storage hoppers, particle emissions (PM10) into the air are frequently produced. Depending on the type of clay storage, there will be more emissions in addition to the normal emissions from manipulation.

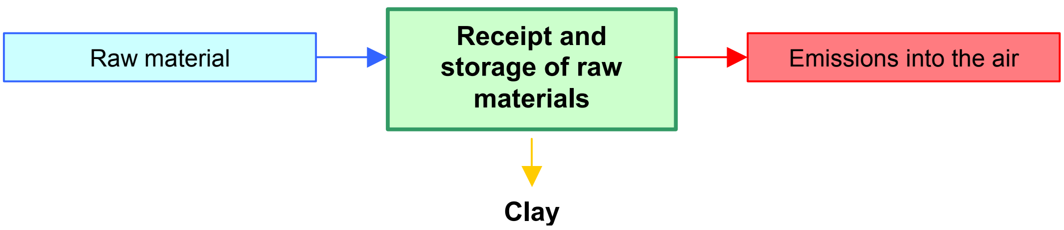


Figure 3.3: Environmental aspects of the process of receipt and storage of raw materials

Transportation of raw materials within the installation

The clays are transported within the plant by means of conveyor belts which can be of three types: steel, rubber or mesh.

Steel sheet belts are normally used in horizontal and rectilinear stretches over long distances. These are generally more resistant to impacts, but due to their price they are used very rarely in the ceramics industry.

For rectilinear stretches and stretches with a medium slope, rubber belts are used as the material to be transported is gripped better and does not slide off.

Lastly, mesh conveyor belts, which are slower than rubber belts, are used for the transportation of heavy loads, for curves or for steep slopes.

Clays that are highly plastic and excessively moist may give rise to problems, as they tend to stick to the belts. This trapped clay dries and does not fall off, and therefore it is of the utmost importance to clean the belts after unloading.

Image 3.2: Transportation of clay within an installation using rubber belts

It should be highlighted that during the transportation of the clays within the installation, it is possible that there may be some emission of particles into the air and detachment of raw materials that may subsequently become waste.

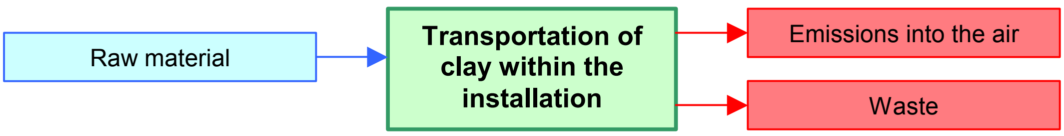


Figure 3.4: Environmental aspects of the process of transporting clay within the installation

3.3. GRINDING

a. Process

During the grinding process, untreated clay direct from the quarry is milled, and raw material with the grain-size distribution and texture necessary for later shaping is obtained. This can be done in two different ways, using the dry method or the semi-wet method.

Dry, hard clays are best prepared in installations using the **dry method**. This type of system ensures that a significant proportion of fine particles are obtained which can then be moistened more easily and more quickly, resulting in a highly homogenous mass with greater plasticity. As a result, a better finish and a stronger product are obtained, both of the dry material and the fired product.

On the other hand, this process can also be carried out using the **semi-wet method**, in which the clay moistening process can begin in the homogenising bed itself. In these conditions, the water is strongly bound to the clay crystals, resulting in the increased plasticity and cohesiveness of the clay, together with an increased capacity to withstand the rigours of the drying process.

Mixing

In some cases, the ground clay can be mixed with different additives, depending on the quality requirements of the final product. The following are the most commonly used:

- Sand
- Barium carbonate
- Calcined clay
- Spent olives
- Micronised limestone
- Polystyrene
- Petroleum coke

b. Associated technologies

Different types of machinery exist to carry out this process, depending on the type of grinding that is used.

To break up the clay using the semi-wet method, a ***hammer or pan mill*** is used. This consists of a bedplate of welded steel which supports the bearing holders for the vertical axis in the centre, while the grinding chamber and screens are fixed to the edges. The clay is fed in through the centre of the machine, and there is one oscillating scraper to remove the ground material, and another to deposit it in the outer area of the screens, in order for the external roller to complete the grinding process.

If grinding takes place at the mine or quarry, a ***clay crusher*** is used, which can cope with the dry mineral and a maximum of 20 % moisture. This type of machinery can be used for the primary grinding of any non-ferrous material of up to 4 Mohs hardness, even those containing limited quantities of hard stones of up to 5 Mohs.

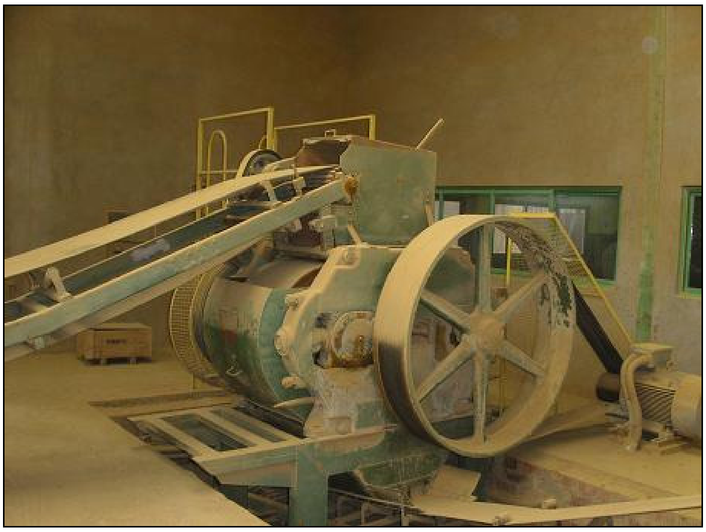


Image 3.3: Dry grinding

Image 3.4: Semi-wet grinding

For the mixing process, the use of a ***rotating feeder shredder*** is also common. This enables an optimal mix of additives and clay to be obtained.

Essentially, this consists of a cylindrical tank with sieves, a vertical axis with a rotor with two scraper arms and a preliminary crusher arm. The mixed mass that comes out of the sieves is deposited onto a collection plate which rotates in the opposite direction from the vertical axis, thus producing an additional mixing effect.

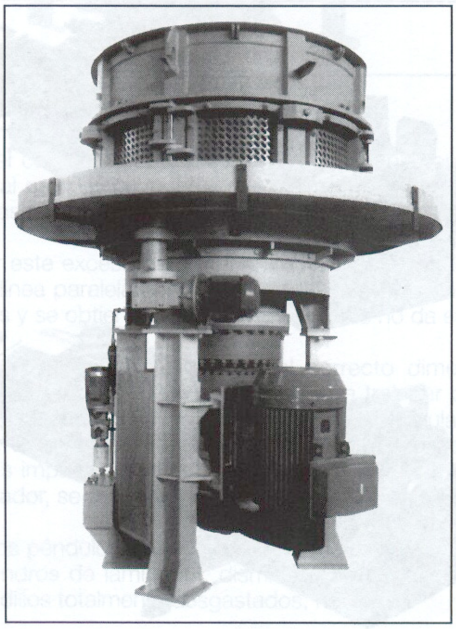


Image 3.5: Rotating feeder shredder

c. Environmental aspects

The machinery involved in this process requires electrical energy to operate. The dry or semi-wet clay is fed directly into the grinder (which is of one type or another depending on the characteristics of the raw material introduced) and is broken up using the mechanisms explained above. During this grinding, emissions of particles into the air are usually produced as a result of the process itself. Noise is also generated.

Once the raw material is ground, certain additives can be added to the ground clay to obtain different qualities in the final product. These are mixed into the clay to obtain a homogenous product.

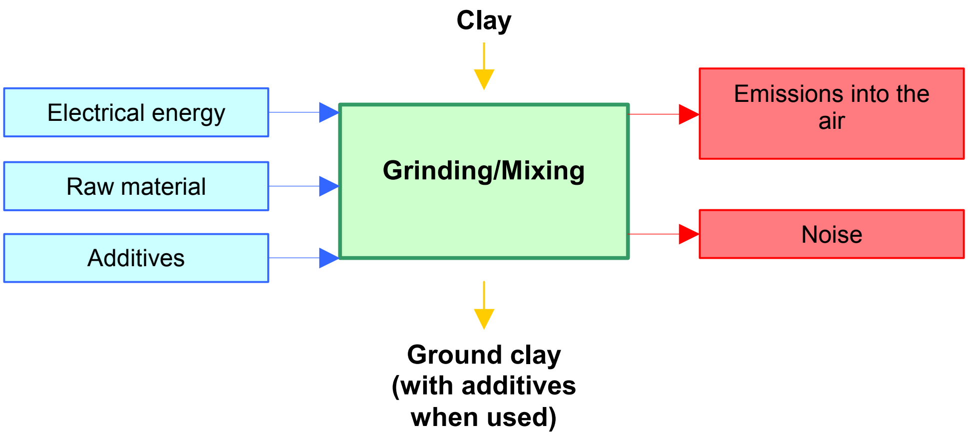


Figure 3.5: Environmental aspects of the grinding process

3.4. SHAPING

3.4.1. Tempering

a. Process

The clay should be sufficiently moist (in general with a level of between 12 and 15 % moisture) in order to be kept together when being worked. During tempering, the quantity of water in the clay mixture is regulated by means of the addition of water or steam (steam may come from an auxiliary boiler).

b. Associated technologies

To temper the clay, structural ceramics plants use a ***pug mill***, a machine specially designed for the homogenisation of clay mixtures and the incorporation of additional water or of colorants and additives.

The machine consists of a self-supporting frame, the tempering tank and the blades. On turning, the blades ensure that the clay, together with the water and the additives, forms a homogenous paste with the necessary plasticity.

Image 3.6: Pug mill

c. Environmental aspects

This process involves the consumption of electrical energy due to the operation of the machinery itself. In addition, the moisture required for the clay can be obtained in two ways: by the direct addition of water to the mixture; or by using steam produced by an auxiliary boiler. In the latter case, emissions into the air are produced due to combustion in the boiler and the type of fuel used.

Lastly, noise is generated from the operation of the machinery, although this is not usually as significant as it is in the grinding process.

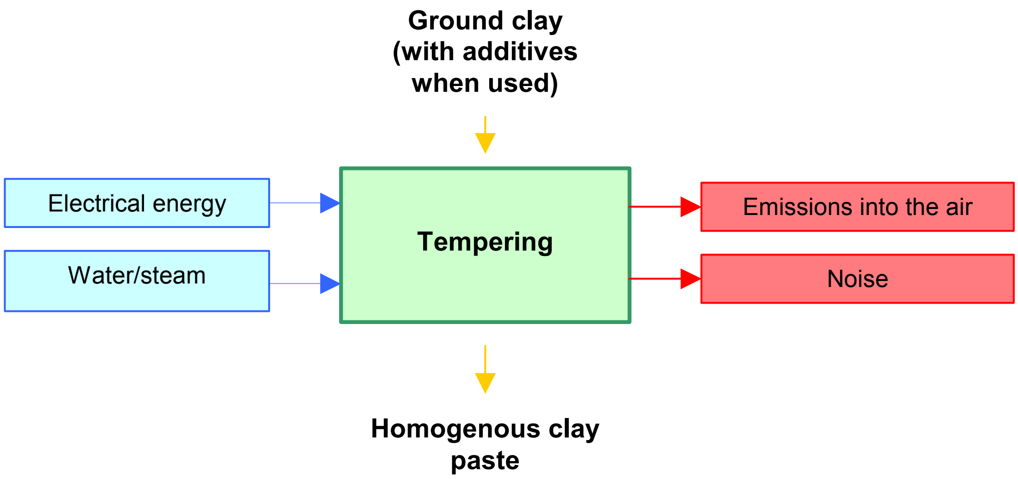


Figure 3.6: Environmental aspects of the tempering process

3.4.2. Moulding

a. Process

In the case of moulding, the process can differ, depending on the material to be manufactured. In the case of bricks, hollow bricks and blocks, the process used is extrusion, while in the case of roof tiles, pressing is also used.

In extrusion, the moistened clay paste is pushed through a perforated mould by a rotating blade. The extruded clay takes on the shape of the outlet nozzle, and can be modified depending on the type of piece to be produced.

Press moulding is preceded by extrusion, which enables a moist cake of clay to be obtained. This is used to fill a mould, which then passes through a press where the paste is compressed to obtain the roof tile.

The effect of pressing and extrusion gives the clay better capacity to absorb water, resulting in a very homogenous paste. The clay is less sticky and can be manipulated with fewer problems.

b. Associated technologies

The ***dealring extrusion machine*** exists for this process. This is a machine designed for clay moulding. It consists of two zones: on one side a deairing zone, which has side doors, and the clay feeding blades on the other side; and the moulding zone, which consists of the extruding press, which has a mould to produce the cake or mass of clay in the desired shape.

The following diagram shows the layout of a roller extrusion press in which the flow of tempered clay is continuous and deairing can take place:

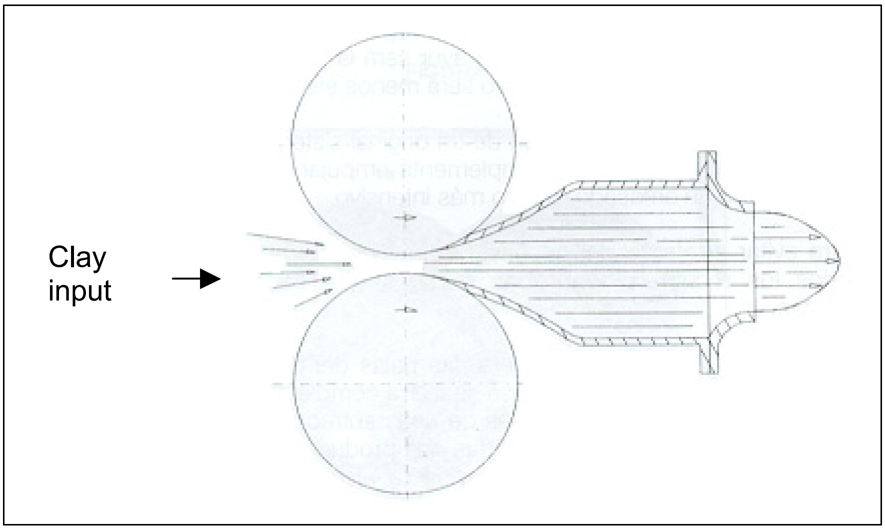


Figure 3.7: Roller extrusion press

Image 3.7: Extrusion machine

c. Environmental aspects

As in the cases above, the equipment used for moulding consumes electrical energy during operation and can generate noise (although in general this is of little significance). In addition, there is also the possibility that inert waste can be produced during moulding, specifically in the form of defective material that is not used for the subsequent process, but instead is separated from the already-moulded product.

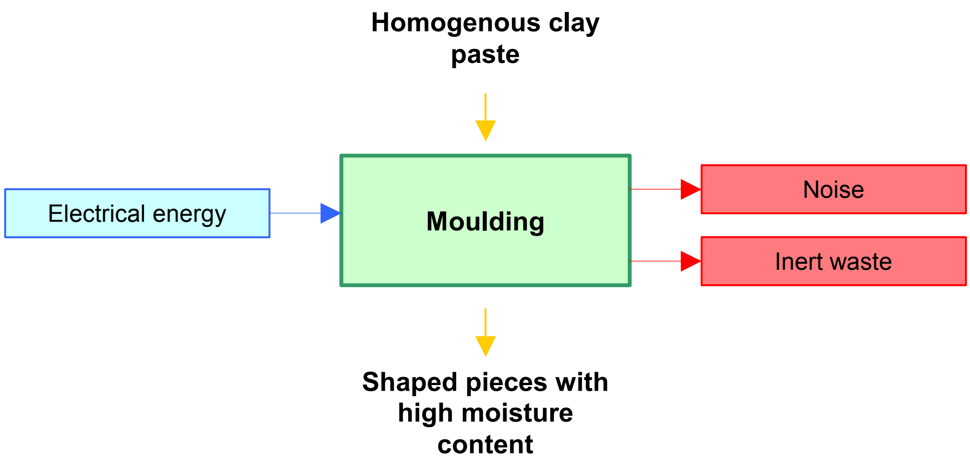


Figure 3.8: Environmental aspects of the moulding process

3.5. DRYING

a. Process

The objective of the drying process is to reduce the moisture content of the pieces before they are fired. It is a complex operation that is influenced by numerous factors: the nature of the clay, the degree of preparation and homogenisation, tensions that may have resulted from the moulding process, the design and format of the piece, the uniformity or otherwise of drying, etc.

The type of drying that is used will influence the strength and final quality of the piece after firing.

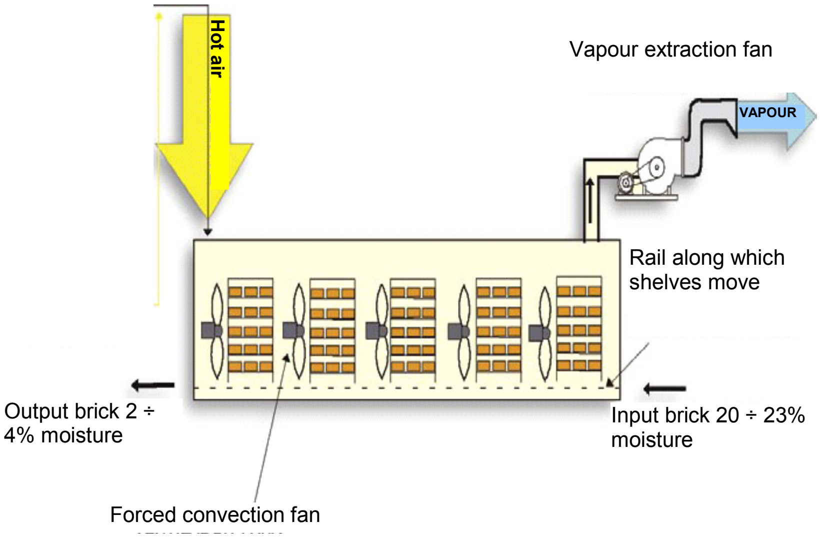
Drying may be either natural or artificial.

For **natural drying,** the material is placed in sheds or in the open air, where its moisture content decreases until the optimum level for firing is reached.

Artificial drying uses heat sources of different origins. In general, cooling gases from the firing kiln are usually taken advantage of for the drying process itself (and therefore no additional emissions are produced). The use of cogeneration furnaces is also common in the sector for drying the pieces produced. This type of technology will be analysed in Section 3.8.1.

Another possible heat source are the gases from burners (using different types of fuel) that, through the combustion process, heat the air in the dryer, which is then distributed throughout the whole dryer area using fans.

The material loaded into the dryer is introduced with a high level of moisture, which is reduced to a level of approximately 2 % by the circulation of large amounts of hot, dry air (between 90 and 110 ºC). When a moisture level of 2 % is obtained, the material is ready to be loaded into the kiln.



Source: Autonomous Government of Andalusia

Figure 3.9: Diagram of a brick dryer

b. Associated technologies

Dryer: construction intended for the reduction of moisture levels in the ceramic pieces produced. It has two parts:

1. Chamber, usually built of refracting bricks

2. Installations

- HEAT INTRODUCTION SYSTEM for the introduction of hot air from different sources.

- AIR MOVEMENT SYSTEM, consisting of fans of different sizes and power that move the air so that it flows as homogenously as possible through the whole dryer.

On some occasions use is made of a **car loader-unloader**, which is a machine designed for unloading the trolleys from the dryer and forming packages of ceramic material on the cars which are then introduced into the kiln.

Image 3.8: Fans for the movement of air within the dryer

c. Environmental aspects

In this case, the consumption and the emissions generated will depend on the type of dryer that the installation has. In the case of natural drying, the moulded material is placed in sheds or in the open air, where its moisture content decreases until the optimum level for firing is reached. The use of fans to encourage the movement of the air is common in order to ensure greater uniformity in the drying process. In this case, there is some consumption of electrical energy.

In contrast, in those installations with artificial dryers, there is some fuel consumption for the generation of heat, and therefore emissions into the air are generated due to the combustion process, the composition of which, as outlined above, will vary depending on the nature of the fuel.

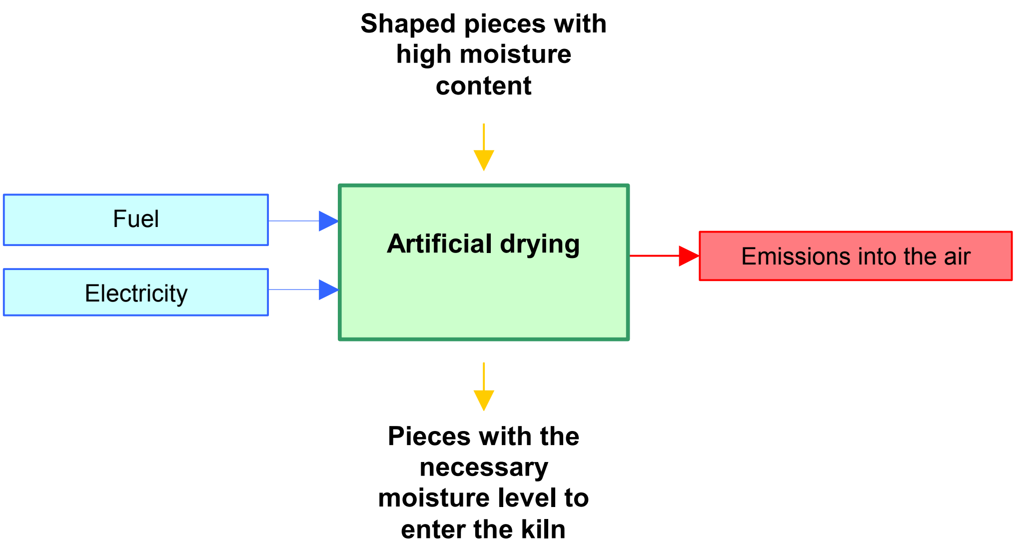


Figure 3.10: Environmental aspects of the drying process

3.6. FIRING

a. Process

Firing is the most important and delicate stage in the manufacturing of ceramic products. This process gives the piece the desired properties, and shows whether the preceding stages (tempering, moulding and drying) have been carried out correctly or not. The pieces are fired in kilns at temperatures ranging from 875º C to somewhat over 1,000 ºC.

The two types of kiln that are most commonly used in the firing process are detailed below.

b. Associated technology

1. Tunnel kiln

The principle behind the tunnel kiln is that there is a fixed firing zone through which the material to be fired moves. The material is placed in the cars mentioned above, which move along the tunnel.

These kilns have a long tunnel, through which a train of cars on rails is pushed. The lower frame of the cars is protected by a thick covering of an insulating, refractory material, and has a buffer that slides along a corresponding groove in the kiln walls. On the lower edge, there is also a plate which slides on sand for improved airtightness. To protect the wheels against the heat, cool air can be blown in under the cars, along the rails and the wheels. The cars are shaped to each other, with no free space between them, and are pushed through the tunnel using a device designed specially for this purpose.

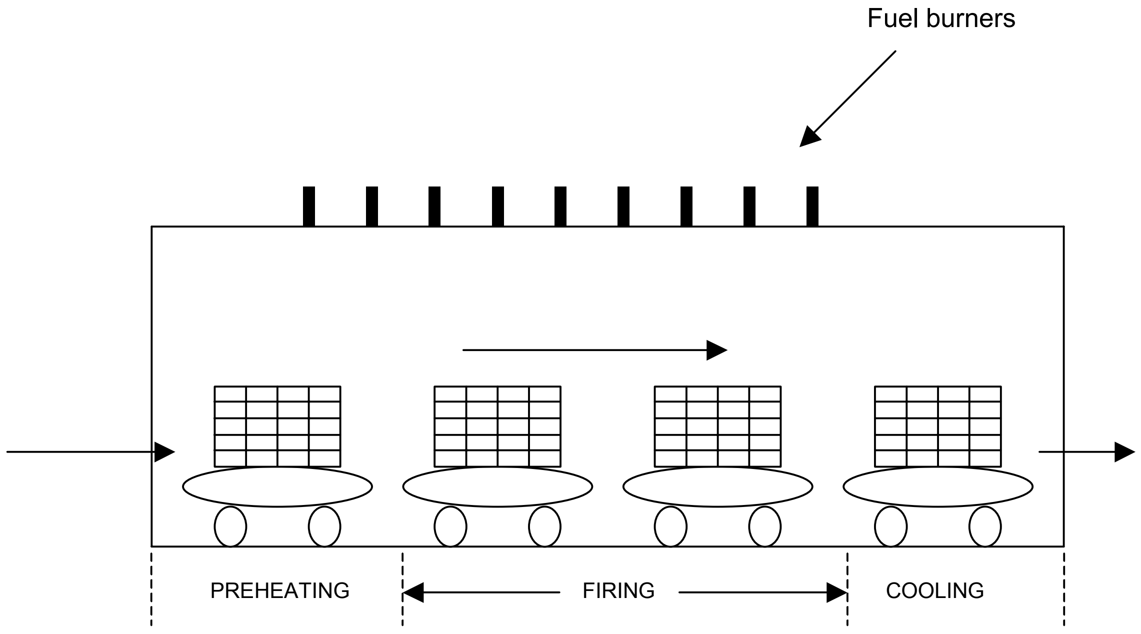


Figure 3.11: Diagram of a tunnel kiln

Inside the kiln there are three zones: preheating, firing and cooling.

- **Preheating:** this zone contains a current of warm air from the firing zone, which circulates in the opposite direction to the material. Normally the heat source is heat recovered from the kiln, and the aim is to remove the moisture content from the material (both the moisture absorbed on the surface and structural moisture). The temperature is progressively increased.

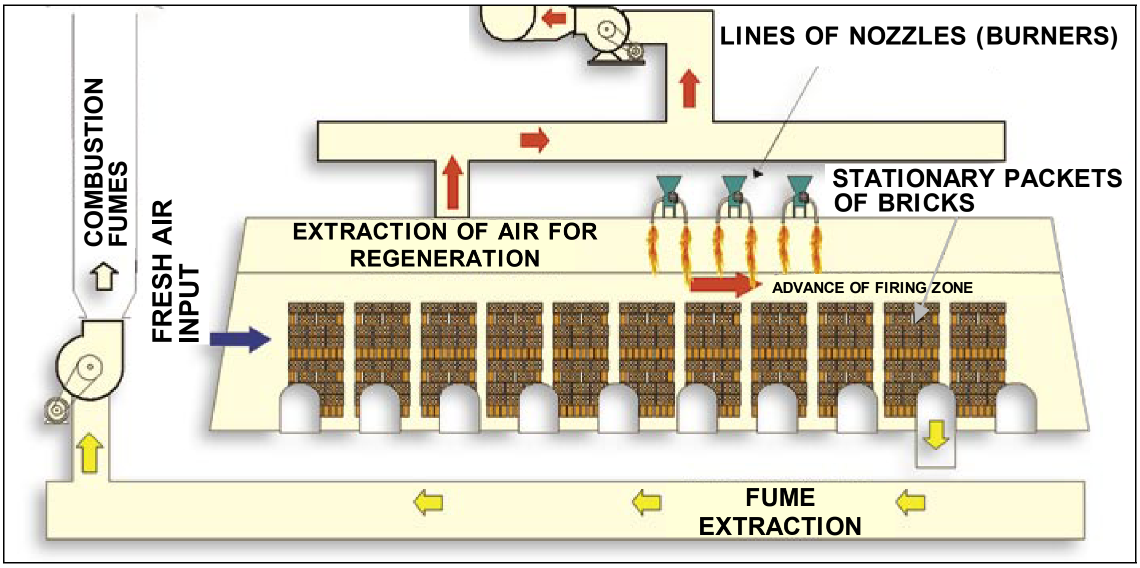
- **Firing:** the fuel burners are used to obtain the optimum firing curve in the central part of the kiln.
- **Cooling:** the material is cooled gradually, in order to avoid cracks in the pieces that would result from sudden temperature change.

Image 3.9: Tunnel kiln, output material after the firing process

2. Hoffmann kiln

In contrast to the tunnel kiln, in this case the material to be fired remains static, while the heat source moves through the different chambers until a firing curve similar to that generated in a tunnel kiln is attained.

This type of kiln consists of a series of joined chambers which are filled with the dry material from the dryer. The burners then move from one chamber to another, firing the material. This system also allows the preheating of the merchandise and the refrigeration of the exhaust gases.



Source: Autonomous Government of Andalusia

Figure 3.12: Diagram of a Hoffmann kiln

The energy efficiency of the two types of kiln is different, as the tunnel kiln has a specific average consumption level of 410 kcal/kg, compared to 480 kcal/kg for the Hoffmann kiln.

c. Environmental aspects

In order to obtain the optimum temperature for the firing of ceramic products (between 875 and 1,000 ºC), significant fuel consumption is required and pollutants are emitted into the air as a result of the combustion process that takes place. It should however be highlighted that, in this case, emissions into the air are channelled as these types of kiln have one or more chimneys emitting smoke externally.

Heat emission is also produced by the hot gases emitted by the kiln.

Lastly, inert waste can be generated in the form of fired pieces that do not meet the required quality or that have some type of defect.

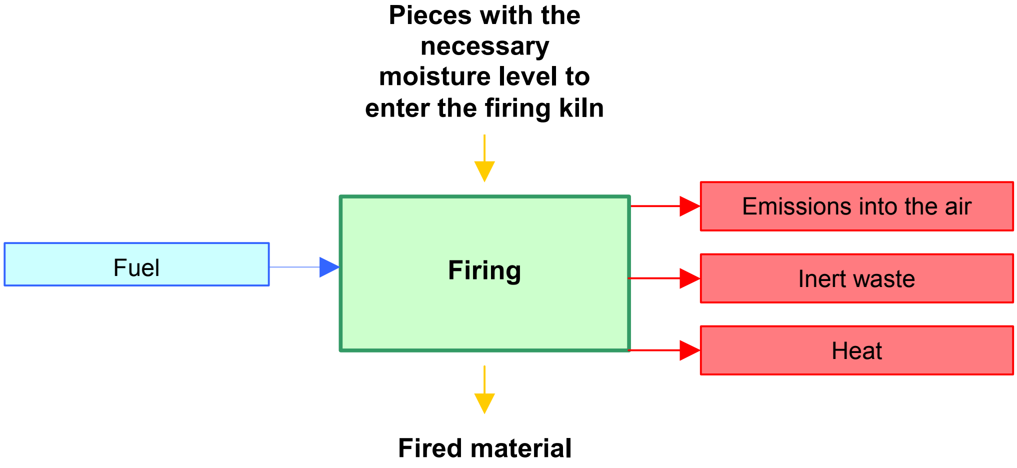


Figure 3.13: Environmental aspects of the firing process

3.7. PREPARATION AND STORAGE OF THE PRODUCT

a. Process

The now-finished pieces are piled up on wooden pallets or on top of each other and may be packaged with shrink-wrap plastic and straps to make their subsequent distribution easier.

In some companies, the finished material is moistened to give it the consistency required by the client. This process can be carried out in two different ways, depending on the installation:

- By moistening the material using a hose.
- By placing the material in pools intended for this purpose.

Storage may be in designated warehouses or in the open air.

Image 3.10: Stacking the material for its subsequent shrink-wrapping

Image 3.11: Storage of the finished product

b. Associated technologies

This process can be carried out manually or using ***packing machines*** to fit straps or to shrink-wrap the packages of finished material.

Image 3.12: Machinery used to prepare material for distribution

c. Environmental aspects

In the process of finishing the product, inert waste is produced from the packaging of the product. This consists of pieces of plastic and pallets broken during handling. When machinery is used, electricity is also consumed.

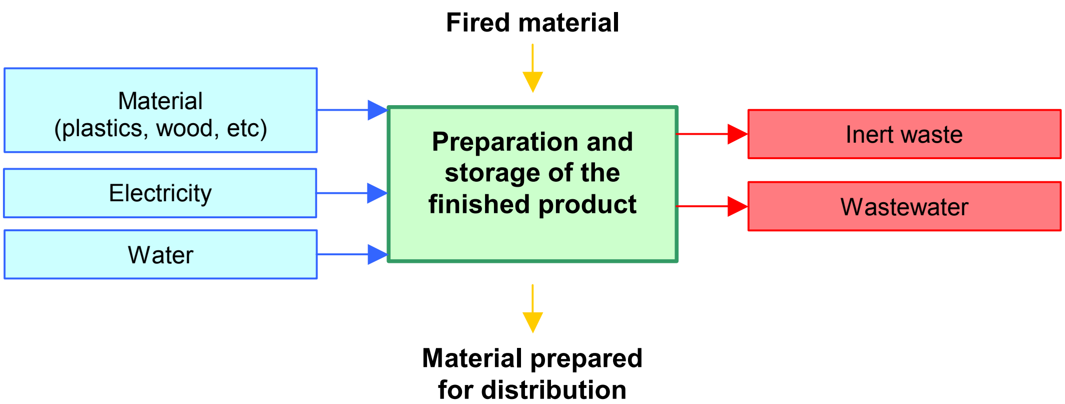


Figure 3.14: Environmental aspects of the storage process of the finished product

3.8. AUXILIARY PROCESSES

This section describes two of the most common auxiliary processes that can be found in some installations in the structural ceramics sector, and that can have some degree of environmental impact: cogeneration and the generation of steam in boilers.

It should be highlighted that not all industries in the sector use this type of technology, as it requires a major investment that companies cannot always afford; nevertheless, it can be found fairly frequently in those countries where the necessary infrastructure is sufficiently advanced.

3.8.1. Cogeneration

The process of cogeneration (the simultaneous production of electrical energy and useful heat energy from a single primary source) is much more efficient than the separate generation of the heat and electricity necessary for industry, and therefore its application is an essential element in energy-saving and environmental conservation objectives, particularly when renewable fuels are used.

Cogeneration systems do not reduce fuel consumption in the generation of electricity itself; their aim is rather to make the most of the potential of the fuel. In this way the chemical energy contained in the fuel is applied to obtaining electrical energy, in addition to obtaining the necessary heat energy produced as a by-product.

The implementation of a cogeneration system implies an increase in the company's overall fuel consumption, but as higher performance is obtained from the process, the overall energy balance is positive.

Put simply, any consumer of thermal energy at a temperature of under 500 ºC can cogenerate it. This means that all consumers of steam, heat transfer fluid, hot water or gases for drying are potential users of cogeneration systems.

The ceramics sector is one of the classic sectors for cogeneration, with energy-intensive use of over 8,000 operating hours per year. The typical application in these cases is the generation of warm air of between 90 and 130 ºC for the dryer, with possible steam generation for extrusion in the extrusion machine.

The concept behind these plants is simple, as the hot gases generated by a turbine or a motor can be used directly in the drying process.

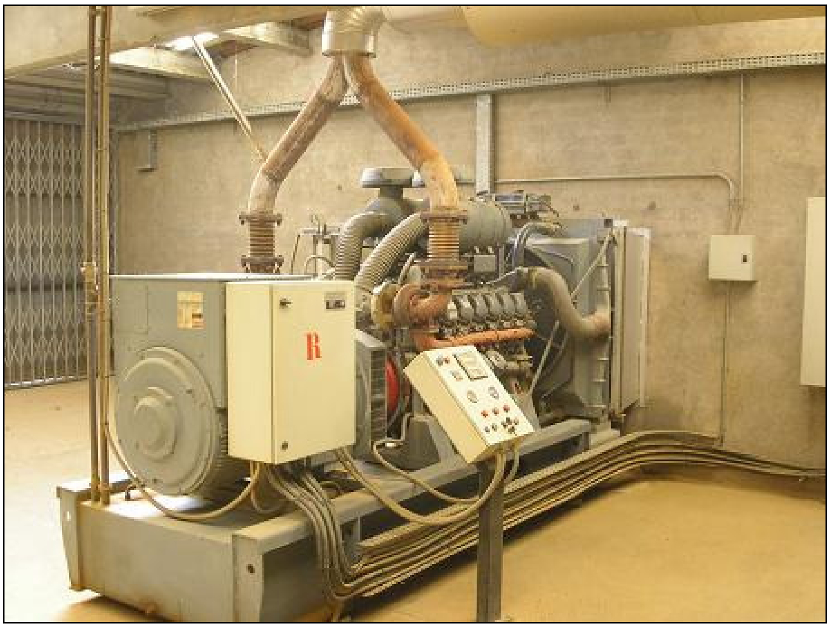


Image 3.13: Cogeneration using fuel oil as fuel

Environmental aspects

The most significant environmental aspects of cogeneration are the emissions into the air produced by the consumption of fuel (normally natural gas) and the generation of noise due to the operation itself, although this is usually of little significance to the environment, as the motors are isolated in separate rooms.

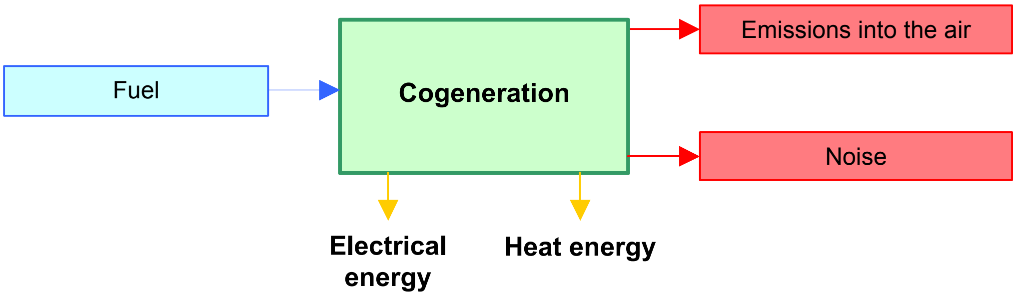


Figure 3.15: Environmental aspects of cogeneration

3.8.2. Steam boilers

In some installations in the sector, moisture is brought to the tempering process (see Section 3.4.1) in the form of water vapour from steam boilers. These boilers are normally operated with natural gas or fuel oil, and provide the clay with sufficient moisture so that it can then be moulded in the extrusion process.

The following image shows a boiler for the generation of steam in a company in the structural ceramics sector.

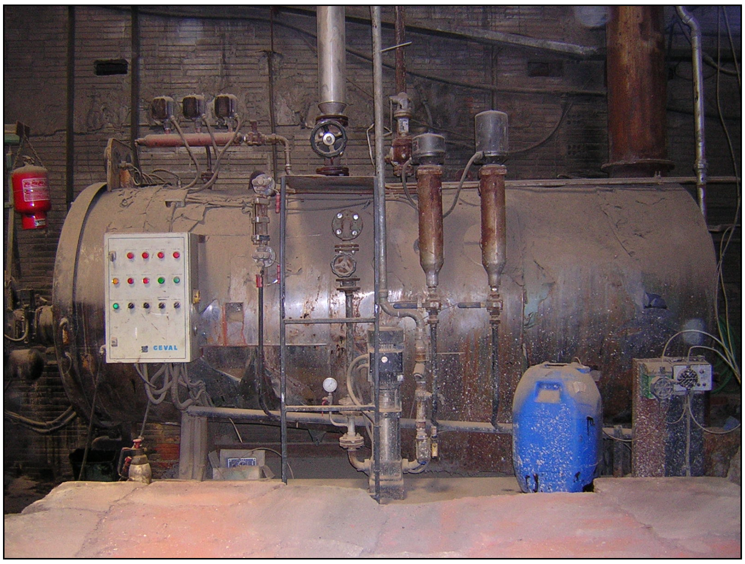


Photo provided by TEULERIA LES FORQUES S.A.

Image 3.14: Boiler for steam generation

The generation of steam by a boiler normally incorporates a process of reverse osmosis for the treatment of tap water. Reverse osmosis is a procedure that is used to guarantee the physical, chemical and bacteriological desalination treatment of the water. It uses semi-permeable membranes rolled into spirals which act as filters, retaining and eliminating the majority of dissolved salts, while also preventing bacteria and viruses from passing through, thus obtaining pure, sterilised water. Water with a high salt content can be treated with reverse osmosis until the limits considered acceptable for its use are reached.

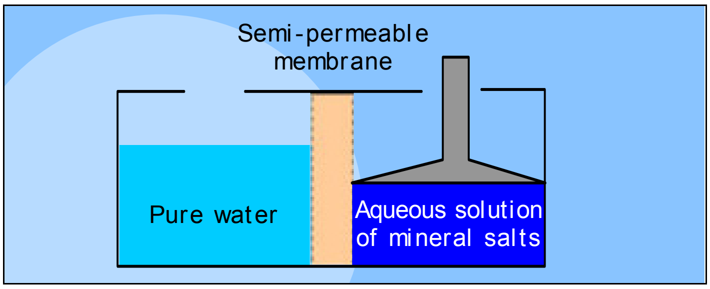


Figure 3.16: Diagram of reverse osmosis

Environmental aspects

The environmental aspects relating to steam generation are, on the one hand, the consumption of fuel required for this operation and therefore the generation of emissions into the air as a result of its combustion, and on the other, wastewaters with a high content in salts which are obtained from the process of reverse osmosis and must be treated.

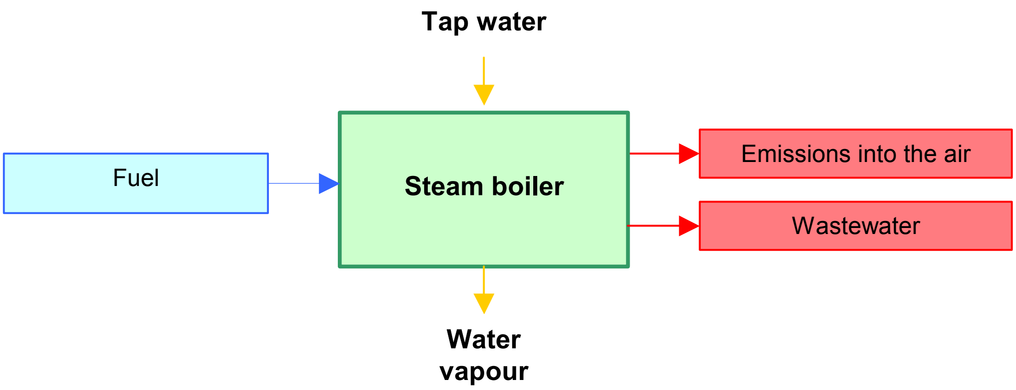


Figure 3.17: Environmental aspects of steam generation by boiler

3.9. SUMMARY OF ENVIRONMENTAL ASPECTS

The diagram below shows the different phases in the process, together with their most significant environmental aspects:

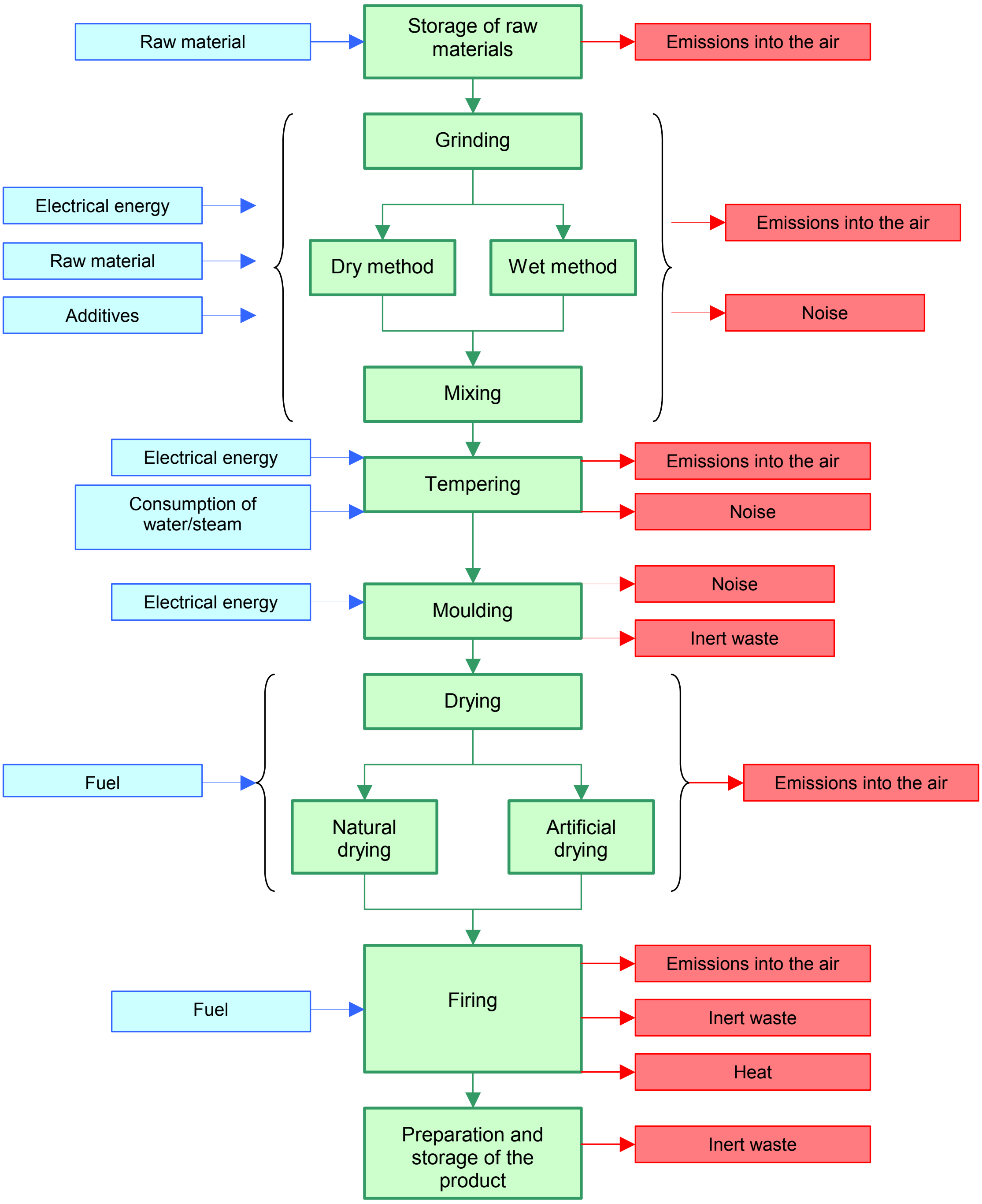


Figure 3.18: Manufacturing process of structural ceramic materials and the associated environmental aspects

Lastly, the following table shows a summary of each of the processes with their associated environmental aspects, providing an evaluation of their importance in accordance with the criteria established at the start of the chapter[1].

[1] **Level A:** Aspect with a very significant environmental impact

Level B: Aspect with a moderate environmental impact

Level C: Aspect with an environmental impact of little significance

Table 3.2: Environmental aspects associated with the manufacture of structural ceramics

STAGE		ENVIRONMENTAL EFFECT	EVALUATION
Storage of raw material		Emissions into the air	B
Grinding / Mixing	**Dry method**	Energy consumption	B
		Emissions into the air	B
		Noise	A
	Wet method	Energy consumption	B
		Water consumption	B
		Noise	A
		Emissions into the air	B
Tempering		Energy consumption	B
		Water consumption	B
		Emissions into the air	B
Moulding		Electrical energy	B
Artificial drying		Fuel consumption	A
		Emissions into the air	A
Firing		Fuel consumption	A
		Emissions into the air	A
		Generation of inert waste	B
		Waste heat	C
Preparation and storage of the product		Generation of inert waste	B
		Water consumption	B
		Generation of wastewater	B

It can be seen that the most significant environmental aspect is the emission of pollutants into the air in the drying and firing processes, which will depend to a great extent on the fuel that is used in both processes, and the consumption of this fuel.

However, the generation of noise during the grinding process should also be noted, as in some cases a high level of noise can be generated.

In terms of electrical energy consumption, taken in individual cases this is not excessive, but taken all together we can see that it is significant in three of the six main processes identified and it should therefore be taken into account within the overall process.

Lastly, water consumption does not have a high environmental impact, while the generation of waste in the process can be significant, and therefore requires analysis in order to minimise it.

4. ENVIRONMENTAL ASPECTS IN THE STRUCTURAL CERAMICS SECTOR

The main environmental aspects concerning the structural ceramics sector are related to significant emissions into the air, above all the emission of particles in the different processes and the emission of combustion gases, for the most part during drying and firing.

There are also other significant aspects, such as the high consumption of electrical energy and water on a global level, and the generation of noise in specific processes. The production of wastewater and the generation of waste during the process are aspects that should be taken into account due to their environmental impact.

It should be noted that the quantification of these aspects can vary from one installation to the next, depending on different factors, such as the size and age of the installation, the quantity of production, equipment, procedures, staff awareness and training, etc.

4.1. ATMOSPHERIC EMISSIONS

As mentioned above, the generation of atmospheric emissions is the most important environmental impact within the structural ceramics sector.

The main emissions into the air in this type of industry are generated during the combustion processes which take place in the kilns and dryers during the firing and drying processes, respectively.

The table below shows an estimate of average pollutant emission values in the manufacture of structural ceramic products, per kg of material produced.

Table 4.1: Average values of atmospheric emissions in the structural ceramics sector

POLLUTANT	AVERAGE VALUE (MG/KG)	EVALUATION [2]
Particles	17.6	A
NO_X shown as NO_2	184.0	B
SO_X shown as SO_2	39.6	C
CO_2	149,000	B
CO	189.0	B
Chlorine and inorganic compounds (expressed as HCl)	4.1	C
Fluorine and inorganic compounds (expressed as HF)	12.7	C
Organic substances, shown as total C	34.5	C
Ethanol	3.1	C
Benzene	2.3	C
Methanol	5.7	C
Phenol	0.7	C

Source: Draft reference Document on Best Available Techniques in the Ceramics Manufacturing Industry (October 2004 version)

[2] Average values of atmospheric emissions in the structural ceramics sector

When considering the figures given in this table, it should be remembered that emissions levels vary depending on the type and quality of the fuel used, the state of the installations, the efficiency of the burners and the control of the combustion process, in addition to the nature of the pollutants found in the combustion gases, which are mainly SO_2, CO, CO_2, NO_2 and particles.

However, there are also emissions of other pollutants, such as Cd, Zn, As, Ni, etc., but these are present only in very small amounts.

The main environmental problems resulting from this are as follows:

- Contribution to the greenhouse effect with significant quantities of CO_2.
- Contribution to the generation of acid rain in the case of fuel consumption with a high sulphur content, and the possibility of cross-border problems due to the location of these industries.
- Contribution to problems on a local scale (pollution of soil and water, etc.) due to the presence of toxic pollutants.

It should also be noted that some auxiliary processes used in the sector (cogeneration or steam generation boilers) can generate additional emissions into the air, and although their contribution will be less than those factors mentioned up to now, they should not be ignored.

4.2. ENERGY CONSUMPTION

Energy consumption is high due to the amount of machinery involved in the process. This factor is affected by the level of mechanisation in the installation in question, as there are many sub-processes that a large number of companies carry out without mechanisation, but rather with the manual completion of these tasks by plant workers.

The following table shows the most frequently used types of energy, together with an evaluation of consumption with respect to the installation as a whole.

Table 4.2: Qualitative evaluation of energy consumption in the structural ceramics sector

PROCESS		ENERGY	LEVEL OF CONSUMPTION	EQUIPMENT
Grinding		Electrical	B	Clay grinder
Tempering		Electrical	B	Pug mill
Moulding		Electrical	B	Extrusion machine
Drying		Heat	B	Burners
Firing		Heat	A	Firing kiln
Auxiliary processes	Cogeneration	Heat	B	Cogeneration motors
	Sub-processes	Electrical	C	Manipulation and transportation of the product

It should be noted that in the table above, the *auxiliary processes* category includes all of the machinery involved in the transportation of the material within the installation, the stacking and preparation of the finished product for distribution, etc.

This consumption of electrical energy will be higher depending on the type of installation analysed and the way in which operations are carried out. The figures in the table are for a company in which the transportation of the material within the plant and its subsequent preparation for distribution are mechanised, and energy is therefore consumed by the machinery involved.

A factor that is very important in the sector, and one which influences the consumption of heat energy, is the fuel used in the combustion processes (Section 6 of the manual provides an analysis of the energy yield and environmental efficiency of the different fuels used in the process), as each fuel has its own characteristics and will therefore have different energetic behaviour during combustion.

Taking into consideration the fact that the two most frequently used types of kiln are tunnel and Hoffmann kilns (described in Section 3.6 of this manual), the following table shows a quantitative evaluation of energy consumption in the firing process depending on the type of kiln used.

Table 4.3: Consumption of heat energy in the firing process by kiln type

FIRING PROCESS		
Type of kiln	**Consumption**	**Observations**
Tunnel	165-340 kcal/kg	N.G., diesel, fuel oil, petroleum coke, biomass
Hoffmann	486 kcal/kg	Mixture of petroleum coke and spent olives

Source: Spanish Ministry of Industry and Energy

In general, the tunnel kiln is more energy-efficient than the Hoffmann kiln, and as a result the use of the Hoffmann kiln has decreased in recent years.

4.3. WATER CONSUMPTION

The structural ceramics sector is characterised by its generally fairly low levels of water consumption. The main processes in which water is consumed are the semi-wet grinding process and the tempering process.

In addition to this, in some cases there are auxiliary processes that use water, such as the moistening of the finished material and in some cases the cleaning of the installations (although this is generally carried out via a dry suction process).

Table 4.4: Qualitative evaluation of water consumption in the structural ceramics sector

PROCESS		LEVEL OF CONSUMPTION	OBSERVATIONS
Grinding by semi-wet method		B	All of the water used is absorbed by the material itself
Tempering		B	All of the water used is absorbed by the material itself
Auxiliary processes	Dampening of finished material	B	Sometimes the material is placed in pools
	Cleaning of installations	C	Usually the cleaning process is carried out using vacuum cleaning

The quantification of water consumption shows that during the process, approximately 6,600 litres of water are consumed per day where water consumption takes place during tempering, with sanitary water use of around 1,000 litres per day, where the number of workers is taken to be 10.

It should be highlighted that these figures may vary depending on the number of workers, the type of process carried out in the installation, whether grinding is dry or wet, and whether the material is moistened prior to distribution.

4.4. NOISE GENERATION

Noise levels are generally of little significance in the structural ceramics sector. The most important process to be taken into account in this respect is the grinding of the clay to attain the appropriate grain-size distribution.

However, those installations with one or several cogeneration motors may have problems with the level of noise they generate.

The rest of the machinery involved in the process usually generates a level of noise that can be considered of little significance in relation to its emission into the environment.

4.5. WASTEWATER

In the industrial sector analysed, the quantity of wastewater that is generated is of little significance, as in the tempering and semi-wet grinding processes, where, as mentioned above, the greatest amount of this natural resource is consumed, the entire amount of water introduced is absorbed to form part of the product.

On the other hand, it should be highlighted that in some companies in the sector in which the clay used as raw material has a high lime content, the finished product is moistened using hoses or placed in pools so that the material hardens and the final qualities required are attained. The water that comes into contact with the product is wastewater, and its original properties are changed as a result of contact with the material. This water should therefore be taken into account among the environmental impacts of the installation.

Lastly, some companies use water in the cleaning of their installations, although the majority use dry methods with vacuum cleaners or suction systems that absorb dust and clay, which are then stored in a container.

4.6. WASTE GENERATION

As in all industrial activities, installations dedicated to the manufacture of structural ceramics generate different types of waste. It should however be highlighted that waste is not generated in large quantities, and that the majority of waste is classified as non-hazardous, according to EWC classifications.

It should be remembered that some of the waste generated is usually reused within the installations themselves, as shown in the table below, which outlines the main waste types generated during the principal processes in the ceramics sector:

Table 4.5: Waste generated during the main processes

WASTE GENERATED DURING THE MAIN PROCESSES			
Waste type	**Process**	**Characteristics**	**Most common treatment**
Ceramic product before the firing process	Moulding	Material discarded during the moulding process	Reuse of the material, introduction into the pug mill
Ceramic products after the firing process	Firing	Product with some type of defect or imperfection on exit from the kiln	Used as filler for roads or quarries
Industrial wood waste	Preparation of the product or storage	Broken pallets generated during the process of stacking the finished product on pallets	Repair of broken pallets, heating for stoves, or discarded
Plastic	Preparation of the product for distribution	Pieces of plastic generated during the process of stacking on pallets or during storage	Discarded

The table below shows the waste generated during the different auxiliary processes that can occur in this type of industry, including the maintenance of installations and machinery, offices, etc.

Table 4.6: Waste generated during auxiliary processes

WASTE GENERATED DURING AUXILIARY PROCESSES			
Waste type	**Process**	**Observations**	**Most common treatment**
Industrial ferrous products	Maintenance of installations	Empty product packaging	Collected by a scrap metal merchant
Sand and clays	Cleaning of installations	– Ceramic dust from the dry cleaning of the installations – Empty cleaning product packaging	– Reuse as raw material – General rubbish
Rags and absorbent materials contaminated with grease and oil	Maintenance operations, leaks, etc.	Occurs during the different manufacturing processes	General rubbish

It can be seen from the tables above that the ceramics sector does not generate a very wide variety of waste types in its processes. However, the quantity of some types that are generated is sufficiently large as to be considered an important environmental impact, also taking into account that, as shown in Tables 4.5 and 4.6, many of these products are not dealt with in the most environmentally suitable way, nor within the recommendations of applicable legislation.

These indications are summarised in the table below, using the evaluation criteria already explained in Section 4 of this manual.

Table 4.7: Qualitative evaluation of waste generated in the sector

	WASTE TYPE	LEVEL OF GENERATION	ENVIRONMENTAL IMPACT
Waste generated during the principal processes	**Ceramic products before the firing process**	High	C
	Ceramic products after the firing process	High	A
	Industrial wood waste	Medium	B
	Plastic	Medium	B
Waste generated during auxiliary processes	**Industrial ferrous products**	Medium	B
	Sand and clays	High	A
	Rags and absorbent materials contaminated with grease	Medium	A

It could be said that the waste with the greatest environmental impact, given its characteristics, is constituted by those materials that have been in contact with lubricating oil, such as rags that have come in contact with it and receptacles that have contained such substances.

In addition, products coming out of the firing process with defects should also be borne in mind, as the level of generation of this type of waste can be high in many cases. The accumulated sand and clays that are generated in the different processes should also be considered, as these can generate a problem throughout the whole installation, given the ease with which they can be diffused.

5. FUELS USED IN THE STRUCTURAL CERAMICS SECTOR

This chapter analyses the main characteristics of the most frequently used fuels in the structural ceramics sector, together with the possibilities for improved environmental performance relating to the use of each of them.

As has been described in earlier sections, the impact caused in the sector by emissions into the air is one of the most important points to be borne in mind. In this context, the use of one fuel or another in the kiln and/or dryer during the firing process, and the performance of this fuel from both an energy yield and an environmental perspective has a significant influence on the atmospheric emissions generated, and on the characteristics of the product.

5.1. MAIN FUELS USED IN THE SECTOR

The use of one fuel or another in the manufacturing industry of structural ceramic products depends on different factors:

- **Availability:** fuels such as biomass, which is in great demand in the sector due to its characteristics, are of intermittent availability, making their consumption difficult at times, as the industry requires a regular supply.
- **Distribution and infrastructure:** some areas do not have the infrastructure necessary for the transportation and distribution of certain fuels, such as natural gas, which is supplied through pipelines.
- **Price:** this is a determining factor in the decision to consume one fuel or another and includes not only its price at any one time, but also any variations that may be anticipated in the future.
- **Environmental efficiency:** in those Mediterranean countries where there is restrictive legislation, this is one of the most important factors to be considered, as the use of a certain type of fuel can mean that the installation fulfils legal requirements or not, with the consequent risk of penalties and environmental damage.
- **Energy efficiency:** the energy efficiency of one fuel or another can also be the reason behind its more or less widespread use in firing kilns in the sector. However, the small amount of information available and the lack of studies providing an adequate contrast make this a secondary factor when a fuel is chosen.

On the other hand, the coming into effect of the Kyoto Protocol on a global level means that those countries that have signed the protocol must reduce their greenhouse gas emissions, and therefore the type of fuel consumed and the way in which it is consumed are becoming decisive factors for some companies.

As mentioned in Section 3 of this manual, the main fuels currently used in the sector are:

- Natural gas
- Conventional and micronised petroleum coke
- Fuel oil
- Coal
- Biomass

For each of these, the following aspects will be analysed:

a. Composition: the chemical composition of the fuel is given.

b. General characteristics and qualitative evaluation: the main characteristics of the fuel (NCV, type of supply, type of storage, etc.) are analysed and a qualitative evaluation is made of each fuel's energy efficiency and environmental impact.

5.1.1. Natural gas

a. Chemical composition

The chemical composition of natural gas is:

Table 5.1: Chemical composition of natural gas

ELEMENT	PERCENTAGE (%)
Carbon	74.5
Hydrogen	23
Sulphur	-
Nitrogen	2.4
Oxygen	-
Others	0.1
Water	< 0.1

It should be noted that the sulphur content in natural gas is so low that it is generally taken to be nil.

b. General characteristics

Table 5.2: General characteristics of natural gas

<table>
<tr><th colspan="3">NATURAL GAS</th></tr>
<tr><th>NCV (kcal/kg)</th><th>PROCESSES IN WHICH IT IS USED</th><th>SUPPLY</th></tr>
<tr><td>11,600</td><td rowspan="3">– Firing
– Auxiliary furnaces
– Drying
– Cogeneration</td><td rowspan="3">By pipeline</td></tr>
<tr><td>STATE</td></tr>
<tr><td>Gas or liquefied gas (LNG)</td></tr>
<tr><td>STORAGE TYPE</td><td>ENERGY EFFICIENCY</td><td>ECONOMIC INFORMATION</td></tr>
<tr><td>———</td><td>In general, natural gas gives a good energy yield during combustion</td><td>High cost. Its price varies depending on oil prices</td></tr>
</table>

5.1.2. Petroleum coke

a. Chemical composition

The chemical composition of petroleum coke is:

Table 5.3: Chemical composition of petroleum coke

ELEMENT	PERCENTAGE (%)
Carbon	87.5
Hydrogen	3.5
Sulphur	5-6
Nitrogen	1.5
Oxygen	1
Others	0.5
Water	< 10

b. General characteristics

Table 5.4: General characteristics of petroleum coke

PETROLEUM COKE		
NCV (kcal/kg)	**PROCESSES IN WHICH IT IS USED**	**SUPPLY**
7,700	– Firing	Land transport
STATE		
Solid		
STORAGE TYPE	**ENERGY EFFICIENCY**	**ECONOMIC INFORMATION**
In warehouses or in the open air	In general, petroleum coke gives a good energy yield during combustion	Lower price than other fuels. May vary depending on sulphur content and HGI

For economic reasons, petroleum coke is often mixed with the clays.

5.1.3. Micronised coke

a. Chemical composition

The chemical composition of micronised coke is:

Table 5.5: Chemical composition of micronised coke

ELEMENT	PERCENTAGE (%)
Carbon	87
Hydrogen	3.5
Sulphur	5-6
Nitrogen	1.5
Oxygen	1
Others	0.5
Water	< 0.5

b. General characteristics

Table 5.6: General characteristics of micronised coke

MICRONISED COKE		
NCV (kcal/kg)	**PROCESSES IN WHICH IT IS USED**	**SUPPLY**
8,300	– Firing	Tanker vehicles
STATE		
Micronised solid (average grain size of some 20 microns)		
STORAGE TYPE	**ENERGY EFFICIENCY**	**ECONOMIC INFORMATION**
Silos	The particle size in combination with the circulation of air in the kiln means that the heat is more evenly distributed, resulting in a good energy yield	The price of micronised coke is higher than that of petrol coke and lower than that of the other fuels

One of the advantages of micronised coke over conventional coke is that it is transported in tanker vehicles and stored in silos, which means that the emission of particles into the air is eliminated during the transportation, loading, unloading and storage processes.

5.1.4. Fuel oil

a. Chemical composition

The chemical composition of fuel oil is:

Table 5.7: Chemical composition of fuel oil

ELEMENT	PERCENTAGE (%)
Carbon	86
Hydrogen	11
Sulphur	1
Nitrogen	1
Oxygen	-
Others	1
Water	< 0.2

b. General characteristics

Table 5.8: General characteristics of fuel oil

FUEL OIL		
NCV (kcal/kg)	**PROCESSES IN WHICH IT IS USED**	**SUPPLY**
9,700	– Firing – Cogeneration	Tanker vehicles
STATE		
Liquid		
STORAGE TYPE	**ENERGY EFFICIENCY**	**ECONOMIC INFORMATION**
Tank	The low ignition temperature means that it must be pre-heated. Good behaviour during combustion	High cost. The price fluctuates depending on oil prices

5.1.5. Coal

a. Chemical composition

Depending on the pressure and temperatures that have formed them, there are different types of coal: peat, lignite, bituminous coal and anthracite.

Peat is very low in carbon and is a very poor fuel. Lignite is next on the scale, but continues to be a poor fuel, although it is used in some power stations. Bituminous coal has a much higher carbon content and has a high calorific value and as a result it is much-used, for example in energy production plants. Anthracite is the best of the coals, as it pollutes very little and has a high calorific value.

From the point of view of elements, coal consists mainly of C, H and O, with lower proportions of N and S.

The main characteristics of the different types of coal are:

Table 5.9: Characteristics of the different types of coal

Characteristics	Bituminous coal	Anthracite
Moisture (%)	10-25	3-5
% C	35-70	85-95
% Volatiles	25-50	2-10
% Ash	10-15	2-5
Energy value (kcal/kg)	4,000-7,000	7,000-8,500

And its approximate elementary composition:

Table 5.10: Chemical composition of the different types of coal

Characteristics	Bituminous coal*	Anthracite*
H_2O (moisture)	15	2
Carbon	60	86
Hydrogen	4	3
Nitrogen	7	3
Oxygen	3	1
Sulphur	1	1

* *Figures expressed as % of mass*

b. General characteristics

Table 5.11: General characteristics of coal

CHARBON		
NCV (kcal/kg)	**PROCESSES IN WHICH IT IS USED**	**SUPPLY**
Depends on the type of coal	– Firing	By truck
STATE		
Solid		
STORAGE TYPE	**ENERGY EFFICIENCY**	**ECONOMIC INFORMATION**
In warehouses or in the open air	Its low NCV, together with the generation of large quantities of ash, makes it of low efficiency	Its price is between the prices of petroleum coke and gas

Coal consumption in the ceramics sector is disappearing in favour of other fuels that are more efficient in energy and environmental terms, such as petroleum coke and natural gas.

5.1.6. Biomass

The main characteristics of one of the types of biomass used in the industry, oilseeds, are shown here. Its composition and other details can vary depending on the type of biomass.

a. Chemical composition

The chemical composition of oilseeds is:

Table 5.12: Chemical composition of oilseeds

ELEMENT	PERCENTAGE (%)
Carbon	50.00
Hydrogen	6.40
Sulphur	0.11
Nitrogen	1.20
Oxygen	34.50
Chlorine	0.10
Others	8.69

b. General characteristics

Table 5.13: General characteristics of biomass

BIOMASS		
NCV (kcal/kg)	**PROCESSES IN WHICH IT IS USED**	**SUPPLY**
Between 2,831 and 4,541 (depending on moisture levels)	– Firing – Drying	By truck
STATE		
Solid		
STORAGE TYPE	**ENERGY EFFICIENCY**	**ECONOMIC INFORMATION**
In warehouses or in the open air	Its low NCV means that it is of low energy efficiency	Its cost is high and variable, linked mainly to its availability

5.1.7. Emissions produced

In this section, the emissions produced by each of the fuels is compared, based on details of emissions obtained from different official sources:

Table 5.14: Emissions breakdown for each type of fuel

	KILN TYPE	NATURAL GAS	PETROLEUM COKE	FUEL OIL	COAL	BIOMASS
SO_2 (kg/tonne of production)	**Tunnel**	0.335 (E)	1.17 (C)	2 (C)	3.665 (C)	0.335 (E)
	Hoffmann	___		2.950 (E)	6.065 (E)	___
CO (kg/tonne of production)	**Tunnel**	0.030 (C)	0.17 (C)	0.060 (C)	0.715 (C)	0.8 (C)
	Hoffmann	0.075 (C)		0.095 (C)	1.195 (C)	___
CO_2 (kg/MJ)	**General**	0.05629 (N)	0.09919 (N)	0.07748 (N)	0.0946 (N)	0.096 (N) Sawdust, oilseeds, etc.
NO_2 (kg/tonne of production)	**Tunnel**	0.090 (C)	0.34 (C)	0.550 (C)	0.725 (C)	0.185 (E)
	Hoffmann	0.250 (C)		0.810 (C)	1.175 (C)	___
Particles (kg/tonne of production)	**General**	0.435	Not available	Not available	0.7	0.425

E: source EPA; C: source CORINAIR, N: Figures published for Spain by the Secretariat of the United Nations Framework Convention on Climate Change

Taking these figures into account, first of all it can be said that emissions from a Hoffmann kiln are generally higher than those from a tunnel kiln, regardless of the type of fuel used. This fact, together with their lower energy yield, has resulted in a decrease in the use of this type of kiln in the sector, particularly in those countries where the economy and available technology enable a change of this scope within the installation.

Secondly, it can be seen that the fuels with lowest emissions are natural gas and biomass, followed by petroleum coke, with fuel oil and coal last in line with their higher pollutant emissions.

The higher sulphur content of fuels such as petroleum coke and fuel oil does not present a problem in the sector in terms of SO_2 emissions, as the firing of clays in the ceramics industry takes place in kilns in which the combustion gases are in contact with the product, and the composition of the clays means that a significant proportion of the SO_2 is retained by the final product, without it being emitted into the atmosphere in the form of gaseous pollutants.

Analysing emissions controls and comparing the results of these with those results that could be expected if all of the SO_2 produced during combustion were emitted, it can be estimated that between 60 % and 80 % of the sulphur dioxide produced is retained.

It should be highlighted that this absorption has no negative effects on the macroscopic physical properties of the final product and in fact improves its external appearance.

5.1.8. Comparison of fuels

Having analysed the main characteristics of the fuels that are most widely used in the sector, the main advantages and disadvantages of each one are now outlined in this section.

Table 5.15: Advantages and disadvantages of the use of the different fuels in the structural ceramics sector

FUEL	ADVANTAGES	DISADVANTAGES
Natural gas	• Lower emissions into the air than the other fuels • High NCV • Easy and clean transportation	• High price • The necessary infrastructure does not reach every installation
Petroleum coke	• Low price • Can be mixed with the clays • Availability	• Particle emissions may be produced during transportation and storage • Moderate emissions into the air • High sulphur content (although emissions are catalysed during the process)
Micronised coke	• Low price • Transport and storage do not generate particle emissions • Higher NCV than conventional coke • Availability	• Moderate emissions into the air • High sulphur content (although emissions are catalysed during the process)
Fuel oil	• High NCV • Storage and transportation without generating emissions	• Significant emissions into the air during combustion • High price • Difficulty to manipulate in pre-combustion • Danger of storage in old installations
Coal	• Medium price • Availability	• High emissions into the air • Storage and transportation can generate high levels of particle emissions
Biomass	• Is not counted in terms of CO_2 emissions (an advantage with regards to the Kyoto Protocol) • Its use is rewarded in many countries	• High price • Intermittent availability • Generally not used in the firing process

6. OPPORTUNITIES FOR POLLUTION PREVENTION IN THE STRUCTURAL CERAMICS SECTOR

With the intention of improving the environmental behaviour of the industries in the structural ceramics sector, this chapter outlines some actions aimed at pollution prevention and the reduction of pollution generated during the manufacturing process. However, a number of factors can affect the viability of applying these types of measures. The most notable of these are:

- Available technology.
- The economic situation of the company.

For these reasons and in order to produce a manual that can be applied to as great an extent as possible to all of the countries that make up the Mediterranean region, the aim has been not to consider those actions that, due to their high economic cost, can only be taken by companies with significant capacity for investment. To this end, those opportunities with a short-term period of return on the investment made are analysed, giving priority to those opportunities that enable pollution to be reduced at source, rather than the use of end-of-line techniques, which are generally more costly.

The opportunities for pollution prevention have been classified according to the following points:

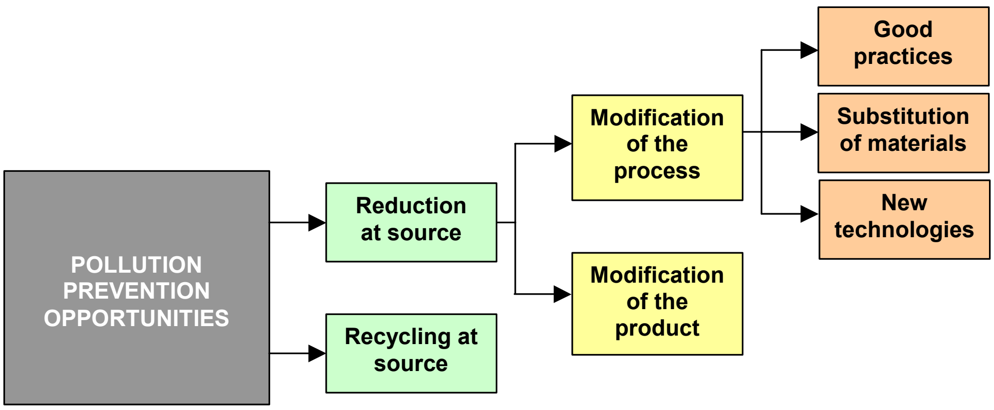


Figure 6.1: Classification of pollution prevention opportunities

For which the definitions are:

- **Reduction at source:** eliminating or reducing pollution (or its danger to the environment) before it is generated, by means of modifications to the process, the use of good housekeeping practices, changes to materials and to the product, or the use of technologies that are more environmentally sound.
- **Recycling:** the opportunity to reuse a waste flow in the same process or in another process (if this takes place in the same production centre, it is considered to be recycling at source).

For each of the pollution prevention opportunities, the following aspects are evaluated:

Table 6.1: Basic diagram for each of the pollution prevention opportunities

<table>
<tr><th colspan="4">OPPORTUNITY-N: NAME OF THE OPPORTUNITY</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Classification of the opportunity according to Figure 3.11</td></tr>
<tr><td>Process</td><td>Production process in which the opportunity arises</td><td>Aspect affected</td><td>Environmental aspect affected by the opportunity</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The environmental situation resulting in the need for improvement is described</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Description of the opportunity for prevention</td><td colspan="2">Qualitative evaluation of the economic effects of putting the improvement into practice</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Qualitative evaluation of the environmental advantages and disadvantages of putting the improvement into practice</td></tr>
</table>

Table 6.2: List of pollution prevention opportunities

	POLLUTION PREVENTION OPPORTUNITIES	TYPE OF OPPORTUNITY
0-1	The reduction in the generation of diffuse emissions caused by vehicle circulation	Reduction at source
0-2	The use of less pollutant solid fuels during firing	
0-3	Training maintenance personnel	
0-4	Facilitating waste management	
0-5	The reduction in the generation of hazardous waste	
0-6	The use of dry cleaning processes	
0-7	Regular checking of the machinery	Good practices
0-8	The installation of regulators in the hoses used for moistening the finished product	
0-9	The regulation of the quantity of air pumped into the kiln	
0-10	The control of water used in tempering	
0-11	The control of losses in hydraulic and air circuits	
0-12	The reuse of the product before firing	Recycling at source
0-13	The use of hot gases from the kiln for the drying process	Modification of the process
0-14	The reduction in diffuse emissions during the storage of raw materials and/or fuel	
0-15	The reduction in diffuse emissions from the plant exterior	
0-16	The use of cogeneration to generate steam	New technologies
0-17	The installation of natural gas consumption meters	
0-18	The installation of high-speed burners for kiln preheating	
0-19	Noise reduction during grinding	
0-20	The use of a low-consumption lighting system	
0-21	The installation of dual-flush cisterns	
0-22	Improved air distribution in the dryers	
0-23	The substitution of motors with high performance motors	
0-24	The use of stiff extrusion	

6.1. REDUCTION AT SOURCE

Table 6.3: Prevention opportunity 1

<table>
<tr><th colspan="4">0-1 REDUCTION IN DIFFUSE EMISSIONS CAUSED BY VEHICLE CIRCULATION</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>Vehicle movement</td><td>Aspect affected</td><td>Emissions into the air</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The ground of the site on which the installation is situated is often not asphalted, and this fact, in combination with the movement of trucks transporting raw materials, finished products, fuel, etc. and other vehicles, results in the emission of dust</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">– Paving the ground of the site
– Dampening the ground of the site</td><td colspan="2">The paving of the site does not involve excessively high expenditure for the installation</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in the generation of diffuse emissions (particles). In the case of dampening the ground of the site, water is consumed</td></tr>
</table>

It is advisable to ensure that the zones in which trucks and other vehicles circulate are paved, and their surface should be kept as clean as possible in order to avoid diffuse emissions.

In this context, keeping the ground surfaces of the installation on which vehicles circulate dampened can reduce dust emissions, particularly during the dry seasons.

Table 6.4: Prevention opportunity 2

<table>
<tr><th colspan="4">0-2 THE USE OF LESS POLLUTANT SOLID FUELS DURING FIRING</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>Firing</td><td>Aspect affected</td><td>Emissions into the air</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">As commented in Chapter 5, the use of solid fuels during the firing stage is very common in the sector. In addition to this, the firing of ceramic products is the process in which most direct emissions (due to combustion) and indirect emissions (diffuse emissions from the storage of fuel in the open air) are generated into the air</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The use of environmentally efficient solid fuels, such as micronised coke</td><td colspan="2">The use of petroleum coke as fuel for the kiln involves a change in the technology used (the kiln burners), which involves an investment that would be amortised in different lengths of time depending on the type of fuel originally used</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in diffuse emissions</td></tr>
</table>

As outlined in section 2.2.3 of this manual, micronised coke is a development of conventional petroleum coke, and has a series of characteristics that result in a certain improvement, from an environmental point of view, in comparison to other solid fuels, such as coal. The grain size that is reached after milling (some 20 microns) makes its storage and supply easier.

This type of fuel is stored in silos and it is brought to the kiln through pipelines, which means that it does not come into contact with the open air, and therefore no dust emissions are produced.

Table 6.5: Prevention opportunity 3

<table>
<tr><th colspan="4">0-3 TRAINING MAINTENANCE PERSONNEL</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>Maintenance</td><td>Aspect affected</td><td>Waste generation</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The maintenance process that takes place in structural ceramics installations can generate a significant quantity of waste due to bad practices in the handling of the different products used, such as lubricating oil</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Avoiding the spillage of oil</td><td colspan="2">This opportunity involves no cost to the company</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in the generation of waste</td></tr>
</table>

Lubricating oil is used within companies in the ceramics sector for the machinery involved in the process. The material that comes into contact with possible spillages of this oil due to its incorrect use (dirty rags, sawdust, etc.) should be treated as hazardous waste. In the same way, receptacles that have been used for the oil are also classed as hazardous waste, and are dealt with as part of Opportunity 5.

Providing training to personnel in the correct handling methods of this oil can avoid the generation of a significant amount of waste that should be treated as hazardous, thus reducing the quantity of this waste at source and also cutting waste management costs.

Table 6.6: Prevention opportunity 4

<table>
<tr><th colspan="4">0-4 FACILITATING WASTE MANAGEMENT</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>All</td><td>Aspect affected</td><td>Waste generation</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The generation of waste in the manufacturing process of ceramic products</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The application of measures to reduce the amount of waste generated or to facilitate the transportation and management of waste that is generated</td><td colspan="2">This opportunity is based on good practices that involve no additional costs for the company</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduced waste generation / facilitation of waste management</td></tr>
</table>

As stated in Section 5.6, the structural ceramics sector generates few types of waste, but the amount of some types can be significant. It is therefore important to apply a series of good practices of a general nature that enable the reduction at source of such waste that is generated, or, where this is not possible, that enable its transportation and management.

These measures are as follows:

1. Ensuring appropriate control of products stored in warehouses.
2. Using reusable containers for those products that are used in large quantities.
3. If the installation has a laboratory, avoiding the tipping of substances used into the general water supply, ensuring instead their selective collection and management.
4. Collecting solid waste when dry, in order to facilitate its transportation and management.
5. Collecting waste that is to be recycled, using easily identifiable containers for each type of waste in an area close to the place where the waste is produced.
6. Compacting packaging waste to save storage space and transport costs.
7. Appropriate indication and labelling of hazardous products or waste.
8. Personnel training and awareness-raising.

Table 6.7: Prevention opportunity 5

<table>
<tr><th colspan="4">0-5 REDUCTION IN THE GENERATION OF HAZARDOUS WASTE</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>Maintenance of machinery</td><td>Aspect affected</td><td>Waste generation</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">As a result of maintenance carried out on the machinery involved in the process, significant quantities of oil containers are generated, which should be treated as hazardous waste</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The use of higher capacity container formats</td><td colspan="2">The consumption of containers with a higher capacity results in savings (although not very large) for the installation due to the purchase of these containers and the fact that a smaller quantity of waste must be managed</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduced waste generation</td></tr>
</table>

During the maintenance of the machinery involved in the process of manufacturing ceramic materials, as mentioned in opportunity number 5, a significant amount of lubricating oil is used, with the resulting generation of waste packaging. This waste packaging is classified as hazardous waste according to the European Waste Catalogue (EWC), and as a result, taking its nature into account, this waste should be managed and collected by an authorised waste manager, with the extra cost that this involves.

One way of reducing this type of waste is to purchase this oil from the supplier in containers of a higher quantity format. This will then result in a reduction of hazardous waste produced along with the reduction of the cost of collection of the packaging by the authorised waste manager.

Table 6.8: Prevention opportunity 6

<table>
<tr><th colspan="4">0-6 USE OF DRY CLEANING PROCESSES</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Reduction at source</td></tr>
<tr><td>Process</td><td>Cleaning</td><td>Aspect affected</td><td>Generation of wastewater</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">During the manufacturing process of ceramic products, a large amount of dust is generated that must then be cleaned up by the plant's cleaning equipment. In some installations this process is carried out by hosing down the floors, with the resulting generation of wastewater that this implies</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The use of dry cleaning processes</td><td colspan="2">Vacuum cleaning equipment does not involve a major investment</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in the generation of wastewater</td></tr>
</table>

In installations in the ceramics sector, a large amount of dust is generated due to the handling of the clay itself during the different production processes.

As a result of this fact, cleaning with water can generate a significant amount of wastewater and it is therefore recommended that this process be carried out using dry cleaning equipment.

6.2. GOOD PRACTICES

Table 6.9: Prevention opportunity 7

<table>
<tr><th colspan="4">0-7 REGULAR CHECKING OF MACHINERY</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Good practices</td></tr>
<tr><td>Process</td><td>All</td><td>Aspect affected</td><td>All</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">Insufficient maintenance of machinery can result in the emission of pollutants with respect to the different vectors, together with an increase in waste generation and often greater electricity consumption due to leaks</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Carrying out regular maintenance of the machinery involved in the process to guarantee that it is operating correctly. This maintenance will depend on the specific characteristics of each installation and the type of technology available</td><td colspan="2">In the case of maintenance that is carried out by internal staff, the cost will be lower than in cases where an external service must be contracted</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">The correct maintenance of the machinery will result in a reduction of pollutants for the different vectors, together with reduced waste generation and electricity consumption</td></tr>
</table>

As there is a significant amount of machinery involved in the manufacturing process of structural ceramics, it is necessary to carry out the appropriate maintenance, as this is a good way of reducing emissions and achieving better performance.

The table below shows examples of the machinery involved in the process, together with the correct maintenance to be carried out.

Table 6.10: Maintenance of the machinery

MACHINE	PROCESS	MAINTENANCE	OBSERVATIONS
Hammer grinder	Grinding the clay	Checking the screen for breakage	If the screen is changed before it breaks, the contamination of silos with dust containing impurities can be avoided
Pug mill	Tempering	Regulation of the quantity of water mixed in	If the water content of the clay is correct, the shaped piece will not contain excessive moisture levels (consuming less energy in the dryer)
Conveyor belts	Transportation of the clay within the plant	Cleaning of the belts	The dry clay sticks to the belt, which means that the clay transported slides off, resulting in the generation of waste
Extrusion machine	Moulding the material	Maintenance of plates or input collectors and funnels to the deairing chamber	Good deairing ensures that the piece produced has the correct characteristics

Table 6.11: Prevention opportunity 8

<table>
<tr><th colspan="4">0-8 INSTALLATION OF REGULATORS IN THE HOSES FOR MOISTENING THE FINISHED PRODUCT</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Good practices</td></tr>
<tr><td>Process</td><td>Moistening of finished material</td><td>Aspect affected</td><td>Water consumption / generation of wastewater</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">Often once the material is fired, the product is moistened in order to attain the consistency required by the client. This process generates wastewater, as when the water makes contact with the material, it absorbs particles shed by the product</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The installation of regulators in the water hoses means that the quantity of water used can be controlled at all times and the flow can even be cut off without the need to turn off the tap</td><td colspan="2">The installation of this type of regulator involves very low expenditure which is affordable for all types of installations</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">This type of action results in a reduction in water consumption and in the production of a smaller amount of wastewater</td></tr>
</table>

As explained in Point 4.5, the process of moistening the finished product is the action within the structural ceramics industry that generates most wastewater, as in the other processes, all of the water incorporated is consumed with none being left over (for example in processes such as semi-wet grinding or the tempering process).

There are different types of hose regulators available that can vary according to thickness and the water pressure. A regulator enables quantity and pressure of the water from the hose to be controlled, and also, if necessary, enables the operator to cut off the water flow without having to go to the corresponding tap. This means that the correct amount of water can be used at all times, thus minimising water consumption and the generation of wastewater.

Table 6.12: Prevention opportunity 9

0-9 REGULATION OF THE QUANTITY OF AIR PUMPED INTO THE KILN			
Type of opportunity	Good practices		
Process	Firing	**Aspect affected**	Emissions into the air
Environmental problem			
Incorrect combustion in the firing kiln may result in the presence of unburned gases (mainly CO) due to a lack of air in the process			
Prevention opportunity		**Economic viability**	
The circulation of a good flow of air must be maintained within the firing kiln to guarantee that firing takes place correctly. The airflow ensures that the heat is distributed quickly and uniformly and that the fuel is fully burned, reducing or eliminating the presence of unburned gases in the emissions.		Control by an operator to ensure that the air flow pumped into the kiln is correct involves no extra cost to the company	
		Environmental balance	
		– Considerable reduction in the presence of unburned gases in the gases emitted by the firing process – Savings in fuel	

The regulation of the amount of air pumped into the firing kiln for combustion is a very important factor in the ceramics sector. The presence of excessive CO in the combustion gases is an indication of incomplete (incorrect) combustion.

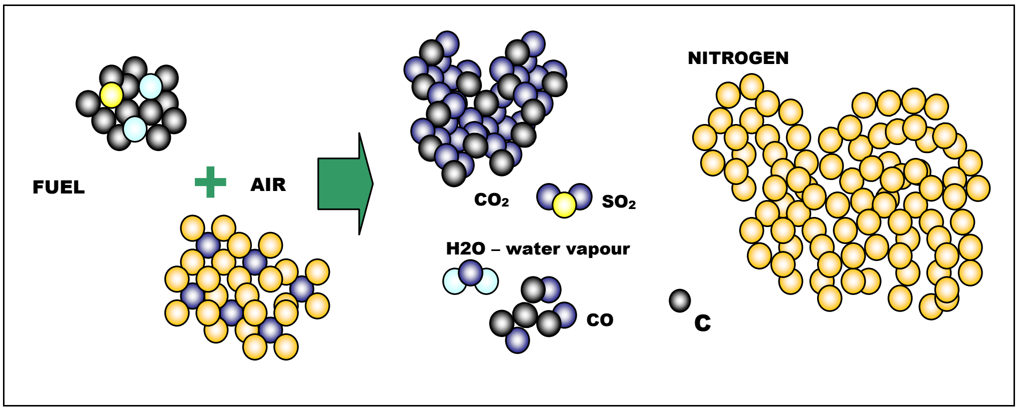


Figure 6.2: Combustion with a lack of air

Table 6.13: Prevention opportunity 10

<table>
<tr><th colspan="4">0-10 THE CONTROL OF WATER USED IN TEMPERING</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Good practices</td></tr>
<tr><td>Process</td><td>Tempering</td><td>Aspect affected</td><td>Energy consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">During the tempering process, a mixture is made of the ground clay with a quantity of water, which is consumed in its entirety. However, an excess of moisture in the clay paste results in greater energy consumption in the drying process</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Adjusting the quantity of water used in the tempering process</td><td colspan="2">This opportunity does not involve any extra expenditure</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduced energy consumption in the dryer</td></tr>
</table>

Adjusting the amount of water used in tempering based on the measurement of the moisture content of the clay-water mix means that the moisture content of the clay paste on output from the extrusion machine can be kept constant, and that the water content of the clay will be slightly lower, thus reducing the energy consumption of the dryer.

This is a practice that does not require major human or economic resources. Once the optimum moisture level of the piece on output from the extrusion machine has been ascertained, depending on the characteristics of the installation (type of clay used, type of dryer, etc.), it is simply a question of carrying out periodic checks that the amount of water added to the process is correct.

Table 6.14: Prevention opportunity 11

<table>
<tr><th colspan="4">0-11 CONTROL OF LOSSES IN HYDRAULIC AND AIR CIRCUITS</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Good practices</td></tr>
<tr><td>Scope</td><td>Control points of the hydraulic and air circuits</td><td>Aspect affected</td><td>Energy consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The losses that occur in the control points of the hydraulic and air circuits can reach up to 25 or 30 % of the power consumed in pumps and fans</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">– Periodic servicing of equipment</td><td colspan="2">The servicing of equipment can be carried out by the company's own operators at no additional cost</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Improved performance and reduced energy consumption</td></tr>
</table>

In addition to the servicing of equipment, there are other types of action aimed at minimising and controlling losses. These are described in Section 7.2 of the chapter on case studies.

6.3. RECYCLING AT SOURCE

Table 6.15: Prevention opportunity 12

<table>
<tr><th colspan="4">0-12 REUSE OF THE PRODUCT BEFORE FIRING</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Recycling at source</td></tr>
<tr><td>Process</td><td>Moulding</td><td>Aspect affected</td><td>Waste generation</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">In the moulding process, the piece with the desired shape is generated. The generation of leftover pieces of clay paste is normal during this process
In addition to this, during the piling up of those pieces that are produced by the extrusion machine, pieces that have been formed but that are defective and must be removed from the process before entering the dryer are also detected</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Firstly, a series of containers can be installed in those zones likely to accumulate this type of waste, so that it can be stored in such a way that the clay is kept clean
When waste is detected and separated it can be reintroduced into the pug mill to be reused in the process, as the qualities of the material have not changed</td><td colspan="2">The process of reintroducing the material can be manual or automatic. In the latter case, the investment required will be higher
The installation of different containers in areas of the company/plant does not involve notable economic outlay</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">The reuse of material in the process reduces waste generation</td></tr>
</table>

The image below shows a container for defective material located in the piling area for defective product items that can be reused after going back through the pug mill.

Image 6.1: Defective products after mixing

6.4. MODIFICATION OF THE PROCESS

Table 6.16: Prevention opportunity 13

<table>
<tr><th colspan="4">0-13 USE OF HOT GASES FROM THE KILN FOR THE DRYING PROCESS</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Modification of the process</td></tr>
<tr><td>Process</td><td>Firing / drying</td><td>Aspect affected</td><td>Emissions into the air / fuel consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">In many installations in the sector, the drying process is carried out by means of the installation of burners that consume natural gas, biomass or other fuels. This type of dryer generates emissions into the air of combustion gases, particles, etc. in greater or lesser proportions, depending on the fuel used</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The use of hot gases from firing for the dryer</td><td colspan="2">The economic viability of the installation of this type of infrastructure will depend on the distance between the kiln and the dryer and the characteristics of the installation. In general it does not involve a major investment</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">This reuse allows the installation to reduce its emission of pollutants into the air. In addition, it leads to a reduction in the company's overall fuel consumption. Another aspect that should be highlighted is the emission into the air of gases with no waste heat</td></tr>
</table>

This is a technique that is becoming more and more widespread in newly built installations, as it is easy to incorporate into the initial design.

Nevertheless, as mentioned above, the distribution of the machinery in the plant and the characteristics of the machinery will, to a large extent, determine the viability of installing this type of system.

In general this is an opportunity that provides good results, although its installation does not eliminate the possibility of some companies requiring supplementary burners to ensure that the material dries correctly.

Table 6.17: Prevention opportunity 14

<table>
<tr><th colspan="4">0-14 REDUCTION IN DIFFUSE EMISSIONS DURING THE STORAGE OF RAW MATERIALS AND/OR FUEL</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Modification of the process</td></tr>
<tr><td>Process</td><td>Storage of the clay</td><td>Aspect affected</td><td>Emissions into the air</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The storage of the raw material and/or fuel in piles outside the installation is an important source of diffuse emissions of dust</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">– Storage in closed warehouses or storage sheds
– Barriers to provide protection from the wind
– Water sprinklers</td><td colspan="2">The investment made by the installation will vary depending on the type of corrective measure installed. The incorporation of wind barriers requires a low investment, ideal for companies that already have external storage areas</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in the generation of diffuse emissions (particles)</td></tr>
</table>

Diffuse emissions are those emissions that are caused by the normal process of production activity that do not have a source of diffused emissions. The most common in the structural ceramics sector are produced by the storage of raw material and/or fuel, and by the circulation of vehicles within the site on which the installation is situated (this opportunity is analysed in section O-1 of this manual).

The main actions that can be taken to avoid diffuse emissions during the storage of raw material and/or fuel are the following:

- **Elimination of external storage in heaps**. The storage of dusty materials in heaps outside the installation can be substituted by their storage in closed warehouses or in storage sheds, which would result in a significant reduction in diffuse emissions.

Image 6.2: Storage of the raw material in a closed warehouse

- **Barriers to provide protection from the wind in external storage areas**. If external storage in heaps is the system that is already in use and is difficult to substitute, it is possible to reduce diffuse emissions of dust by the use of barriers to provide protection from the wind, designed specifically for each individual case.

- **Water sprinklers.** In cases where the source of dust is very localised, a water sprinkler system can be installed using a spray injection system. This type of action considerably reduces particle emissions, although it can generate wastewater.

Photo provided by Cerámica Espíritu Santo, SA

Image 6.3: Water sprinklers for the raw material

Table 6.18: Prevention opportunity 15

<table>
<tr><th colspan="4">0-15 REDUCTION IN DIFFUSE EMISSIONS FROM THE PLANT EXTERIOR</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">Modification of the process</td></tr>
<tr><td>Process</td><td>Transportation of the clay within the installation</td><td>Aspect affected</td><td>Emissions into the air</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">In many installations, the transportation of clay outside of the plant takes place using conveyor belts (see Section 3.2 of this manual) that generate dust due to their movement</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Fitting the conveyor belts with protective barriers</td><td colspan="2">The installation of this type of measures involves a higher cost for existing installations than for companies at the design stage</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in diffuse emissions from the plant exterior</td></tr>
</table>

The image below shoes a conveyor belt with protective barriers incorporated, thus avoiding the emission of dust during the transportation of the clay.

Source: Photograph provided by Cerámica Carbonell

Image 6.4: Covered conveyor belt for the transportation of clay

6.5. NEW TECHNOLOGIES

Table 6.19: Prevention opportunity 16

<table>
<tr><th colspan="4">0-16 USE OF COGENERATION TO GENERATE STEAM</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Tempering/drying/electricity generation in the installation</td><td>Aspect affected</td><td>Emissions into the air/fuel consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">A large part of the machinery involved in the process consumes electrical energy which comes mainly from the supply grid</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The installation of cogeneration motors which can supply the electrical and heat energy required for the process, with no need for connection to the public electricity grid</td><td colspan="2">The original investment required is high, but the yield from a cogeneration motor is high and the leftover electrical energy can be sold</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">This involves fuel consumption and emissions into the air are produced; nevertheless, cogeneration motors are more efficient that conventional motors and therefore for the same fuel consumption, a greater quantity of energy is obtained</td></tr>
</table>

It should be noted that different types of cogeneration motors exist that generally operate with fuel oil or natural gas. Those that use natural gas produce lower overall emissions than those that use fuel oil as their source of fuel.

The energy produced by cogeneration in the industries of the ceramics sector can be used for:

a) Hot air for the dryer

b) Hot combustion gases (if the installation has a prekiln)

c) Steam for tempering (if the installation adds moisture to the clay using steam)

Cogeneration motors are therefore profitable for those installations that use processes with the characteristics mentioned above, and which ensure the full use of the energy generated by the cogeneration motors.

Another environmental aspect that should be taken into account is the generation of noise during their operation, as this can be significant, particularly in the case of older motors or motors that have not been well maintained.

Table 6.20: Prevention opportunity 17

<table>
<tr><th colspan="4">0-17 INSTALLATION OF NATURAL GAS CONSUMPTION METERS</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Firing / drying</td><td>Aspect affected</td><td>Fuel consumption / emissions into the air</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">In general, installations that use natural gas in their processes have a meter that controls the plant's overall consumption. This means that the individual gas consumption of each of the processes and the machines involved is unknown</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Installation of a meter for each of the processes that use this type of fuel</td><td colspan="2">This does not involve a high cost for new installations. However, in existing installations, the investment will depend on the physical characteristics of the plant</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">The individual control of the consumption of natural gas means that the process that consumes most natural gas can be identified, as can increases in consumption, allowing corrective measures to be taken where necessary</td></tr>
</table>

In a sector in which energy costs can be up to 30 or 40 % of manufacturing costs, the implementation of measures to control consumption in themselves mean a considerable energy saving.

The control of consumption and the adoption of measures to reduce it can result in energy saving by the simple act of maintaining the optimum operating parameters of the process over time.

The installation of meters in the different machines that use natural gas makes it possible to identify which machines have the highest consumption levels, whether there are variations in regular consumption, and other aspects that will help the company to take corrective measures.

The image below shows a gas meter installed in a framework of natural gas pipelines, which provides a reading of the volume consumed.

Source: Photograph provided by Ladislao Laguna ceramics

Image 6.5: Natural gas meter

There are different types of meter available on the market at varying prices, depending on their level of sophistication and the information that they provide. The model in the image shows, among other things, the volume of gas, both uncorrected and corrected for temperature and pressure, flow and compressibility.

Table 6.21: Prevention opportunity 18

<table>
<tr><th colspan="4">0-18 INSTALLATION OF HIGH-SPEED BURNERS FOR KILN PREHEATING</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Firing</td><td>Aspect affected</td><td>Fuel consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">One of the stages of the process with greatest fuel consumption is the firing kiln. An increase in consumption implies greater emissions into the air and lower productivity</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The installation of high-speed burners in the kiln preheating area</td><td colspan="2">The installation of this type of technology can only take place in tunnel kilns

This involves a greater investment for existing installations, although it should be remembered that the investment implies an increase in productivity</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">A decrease in fuel consumption together with a reduction of emissions into the air</td></tr>
</table>

Table 6.22: Prevention opportunity 19

<table>
<tr><th colspan="4">0-19 NOISE REDUCTION DURING GRINDING</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Grinding</td><td>Aspect affected</td><td>Noise generation</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The grinding process carried out during the manufacturing of ceramic products generates a significant amount of noise due to the crushing of the clay</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Enclosing of the grinding machinery</td><td colspan="2">The investment necessary for the implementation of this type of measure would be amortised in the medium term</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction of noise generated</td></tr>
</table>

Different types of enclosures are available, but in this case it is thought that the most effective would be a soundproofed enclosure for fixed machinery in the interior of the plant.

This type of enclosure is a structure that covers or encloses the source of noise (in this case the grinding machine) to protect the environment surrounding the machine.

Table 6.23: Prevention opportunity 20

<table>
<tr><th colspan="4">0-20 USE OF A LOW-CONSUMPTION LIGHTING SYSTEM</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Scope</td><td>Throughout the plant</td><td>Aspect affected</td><td>Electricity consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The plant's lighting requires significant electricity consumption</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">Changing the system of switching on and the type of lamps for a more efficient system</td><td colspan="2">An investment in the installation of these systems is amortised in the short term</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in electricity consumption</td></tr>
</table>

The actions involved in installing this type of more efficient system include two aspects:

- The introduction of electronic ballast switches in fluorescent lights operating with starter switches.
- The substitution of mercury vapour lamps with high-pressure sodium vapour lamps.

Table 6.24: Prevention opportunity 21

<table>
<tr><th colspan="4">0-21 INSTALLATION OF DUAL-FLUSH CISTERNS</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Drying</td><td>Aspect affected</td><td>Water consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">Excessive water consumption in the cisterns of sanitary facilities</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The installation of dual-flush cisterns</td><td colspan="2">The investment is recovered in the short term</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduced water consumption</td></tr>
</table>

The installation of dual flush cisterns in the plant's sanitary facilities is a practice that is becoming more and more widespread in the industrial sector, due to the fact that the reduction in water consumption is considerable, and the investment is recovered in the short term.

Table 6.25: Prevention opportunity 22

<table>
<tr><th colspan="4">0-22 IMPROVED AIR DISTRIBUTION IN THE DRYERS</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Drying</td><td>Aspect affected</td><td>Energy consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">Distribution of the air in the dryer can be non-uniform, generating heat losses together with increased energy consumption</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The installation of conical heat distribution fans</td><td colspan="2">The installation of this type of fans does not involve a cost much greater than the cost of installing conventional fans</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduced energy consumption in the drying process</td></tr>
</table>

In tunnel-type dryers, whether they are continuous or batch dryers, air is pumped in through the upper part of the dryer. The installation of conical fans enables the input of hot air to be regulated at all heights of the shelving. In this way, the heat is distributed more uniformly, resulting in improved energy consumption.

The image below shows a conical type fan in a brick dryer, with its characteristic conical shape, which differentiates it from conventional fans[3].

[3] See Section 3.5

Source: Autonomous Government of Andalusia

Image 6.6: Conical fans

Table 6.26: Prevention opportunity 23

0-23 SUBSTITUTION OF MOTORS WITH HIGH PERFORMANCE MOTORS			
Type of opportunity	New technologies		
Process	All those involving machinery that requires motors	**Aspect affected**	Energy consumption
Environmental problem			
In those industries dedicated to the manufacture of structural ceramic products, high power motors are used (in general over 100 and 200 HP) which consume a considerable amount of electricity			
Prevention opportunity		**Economic viability**	
Substitution of conventional electric motors with high performance motors		Taking only the extra costs of the machinery into account, the investment can be amortised in periods of from 1 to 2 years	
		Environmental balance	
		Reduced energy consumption	

Table 6.27: Prevention opportunity 24

<table>
<tr><th colspan="4">0-24 USE OF STIFF EXTRUSION</th></tr>
<tr><td>Type of opportunity</td><td colspan="3">New technologies</td></tr>
<tr><td>Process</td><td>Extrusion</td><td>Aspect affected</td><td>Energy consumption</td></tr>
<tr><td colspan="4">Environmental problem</td></tr>
<tr><td colspan="4">The quantity of energy consumed in the dryer is one of the most important figures in the manufacturing process of ceramic products</td></tr>
<tr><td colspan="2">Prevention opportunity</td><td colspan="2">Economic viability</td></tr>
<tr><td colspan="2" rowspan="3">The use of hard extrusion</td><td colspan="2">The final energy balance is positive and therefore an economic saving is made</td></tr>
<tr><td colspan="2">Environmental balance</td></tr>
<tr><td colspan="2">Reduction in the amount of energy consumed</td></tr>
</table>

By using extrusion machines with the capacity to operate at higher pressure than conventional extrusion machines, the ceramic piece can be shaped with a lower moisture content. As a result, the use of the dryer is rendered practically unnecessary.

One of the environmental aspects associated with this opportunity is the fact that the amount of heat energy consumed during drying is reduced, although the counterpoint to this is that electricity consumption during extrusion increases. In spite of this, the overall energy balance is positive.

6.6. SUMMARY TABLE

The following table provides a summary of the environmental aspects that are affected by each of the pollution prevention opportunities listed in the manual.

Table 6.28: Summary of the environmental aspects affected by the pollution prevention opportunities

	POLLUTION PREVENTION OPPORTUNITIES	ATMOSPHERIC EMISSIONS	ENERGY CONSUMPTION	WATER CONSUMPTION	NOISE GENERATION	FUEL CONSUMPTION	WASTEWATER	WASTE GENERATION
0-1	The reduction in the generation of diffuse emissions caused by the circulation of vehicles	X						
0-2	The use of less pollutant solid fuels during firing	X						
0-3	Training maintenance personnel							X
0-4	Facilitating waste management							X
0-5	The reduction in the generation of dangerous waste							X
0-6	The use of dry cleaning processes			X				
0-7	Regular checking of machinery	X	X	X	X	X	X	X
0-8	The installation of regulators in the hoses used for moistening the finished product		X				X	
0-9	The regulation of the quantity of air pumped into the kiln	X						
0-10	The control of water used in tempering		X					
0-11	The control of losses in hydraulic and air circuits		X					
0-12	The reuse of the product before firing							X
0-13	The use of hot gases from the kiln for the drying process	X				X		
0-14	The reduction in diffuse emissions during the storage of raw materials and/or fuel	X						
0-15	The reduction in diffuse emissions from the plant exterior	X						
0-16	The use of cogeneration to generate steam	X				X		
0-17	The installation of natural gas consumption meters	X				X		
0-18	The installation of high-speed burners for kiln preheating					X		
0-19	Noise reduction during grinding				X			
0-20	The use of a low-consumption lighting system		X					
0-21	The installation of dual flush cisterns			X				
0-22	Improved air distribution in the dryers		X					
0-23	The substitution of motors with high performance motors		X					
0-24	The use of stiff extrusion		X					

7. CASE STUDIES

This section provides details of case studies concerning some of the pollution prevention opportunities described in the previous section. These examples also contain some economic data for the benefits resulting from the application of the pollution prevention options.

It should be noted that the economic benefits can vary from one country to another due to different factors, such as the cost of raw materials, of the energy used, of the workforce, etc. Nevertheless, these case studies are examples that are intended to provide guidelines as to the environmental and economic effects of the application of the opportunities described in this manual.

The following case studies are outlined in this section:

- The use of less pollutant solid fuels
- The control of losses in hydraulic and air circuits
- The regulation of the quantity of air pumped into the kiln
- The reuse of the product before firing
- The use of hot gases from the kiln for the drying process
- The installation of cogeneration
- The installation of high-speed burners in the kiln
- The use of a low-consumption lighting system
- The installation of enclosures to reduce noise emissions
- The installation of high performance motors

7.1. THE USE OF LESS POLLUTANT SOLID FUELS

Background

The use of solid fuels for the firing stage of ceramics is a practice that is very widespread throughout the sector. The process of firing ceramic products is the process during which the greatest amount of emissions into the air is generated, both directly (due to the combustion process) and indirectly (diffuse emissions from the storage of fuel in the open air). These emissions can be quite high, depending on the characteristics of the installation and the area in which it is situated.

Description

Micronised coke is a product that has evolved from conventional petroleum coke. It has a series of characteristics that represent a certain improvement from an environmental point of view in comparison with other solid fuels, such as coal. The size of grain that is obtained following a grinding process (of some 20 microns) makes its storage and supply easier.

This type of fuel is stored in silos and it is fed into the kiln through pipelines, which means that it does not come into contact with the outside air and therefore no dust emissions are produced.

The two images below show firstly the way in which petroleum coke is supplied to the installation, and secondly the storage of this type of fuel in silos.

Image 7.1: Supply of petroleum coke to the installation

Image 7.2: Storage of petroleum coke in silos

It can be seen that in both cases the fuel is kept away from the outside air, thus avoiding any type of emissions (particle generation) resulting from its handling.

Evaluation

As mentioned above, this results in a 100 % reduction in the emission of particles produced as a result of both the storage and the handling of the fuel (unloading supply vehicles).

From the economic point of view, the investment required to make the change from using the initial type of fuel to the use of micronised coke will depend on the original type of fuel that is used in the kiln. The following table shows the return periods on such an investment, depending on the initial type of fuel used:

Table 7.1: Period of return on the investment depending on the initial type of fuel used

INITIAL FUEL	PERIOD OF RETURN ON THE INVESTMENT
Natural gas	18 months
Coal	No estimate available
Fuel oil	20 months

Figures taken for consumption levels of 300t/day

7.2. CONTROL OF LOSSES IN HYDRAULIC AND AIR CIRCUITS

Background

The losses that occur in the control points of the hydraulic and air circuits can reach up to 25 or 30 % of the power consumed in pumps and fans, which in turn results in a considerable increase in the amount of electrical energy consumed.

Description

There are different actions that can be taken with the aim of minimising and controlling losses:

a) Periodical servicing of equipment by the company's in-house staff.

b) The installation of variable speed motors.

c) Fitting equipment with input deflectors.

In addition to this, the insulation of pipes in which either steam or hot air circulate is another way of reducing losses as it considerably reduces the transmission of heat between the pipeline and the air.

Evaluation

The following table shows the savings that can be made by the implementation of each of the options described.

Table 7.2: Saving

TYPE OF ACTION	SAVING	TYPE OF SAVING
Installation of variable speed motors	25-30 %	Electricity consumption
Fitting input deflectors	10-15 %	Electricity consumption
Insulation of pipes	1-3 %	Fuel consumption

7.3. REGULATION OF THE QUANTITY OF AIR PUMPED INTO THE KILN

Background

The generation of smoke during the process of firing ceramic material is one of the most significant environmental aspects of the structural ceramics sector. In relation to this, incorrect combustion in the firing kiln can result in the presence of unburned gases (mainly CO), due to a lack of air during the process.

Description

The circulation of a high airflow must be maintained inside the firing kiln to ensure that firing takes place correctly. In practice, complete combustion cannot be obtained without the introduction of a quantity of oxygen that is higher than the theoretical amount (for stoichiometric combustion).

This is due to the fact that the very consumption of oxygen during combustion reduces its concentration in the air and makes it more difficult for it to react with the fuel that is yet to be burned.

The table below shows the percentage of excess air necessary to obtain complete combustion for each type of fuel.

Table 7.3: Excess air necessary according to fuel type

FUEL	EXCESS AIR (%)
Bituminous coal	35 – 50
Lignite	30 – 40
Anthracite and coke	40
Pulverised coals	25 – 50
Liquid fuels	15 – 25
Gaseous fuels	5 – 15

Evaluation

By optimising the combustion parameters of heat generating equipment, a saving of between 2 and 10 % of fuel can be made.

In addition to this it should be highlighted that in incomplete combustion processes, not all chemical energy contained in the fuel is exploited; moreover there is emission of hydrocarbons.

7.4. REUSE OF THE PRODUCT BEFORE FIRING

Background

During the process of extrusion or moulding (see Section 3.4.2), the material is forced to pass through a nozzle, which forms the piece. It is then cut in order to obtain the appropriate size, according to the desired product to be obtained. During this process, a certain amount of leftover material is generated due to the cut that is made. This material can be reintroduced into the pug mill with no resulting loss of quality of the raw material.

Description

The process described above can be carried out automatically, so that the leftover pieces from the cut are reintroduced into the pug mill via a system of conveyor belts that collect the material that is to be reused.

In addition to this, it should be noted that during the process of stacking the material before it goes into the dryer, it is common for some of the pieces to be broken, and a series of containers can be provided for the accumulation of such defective pieces, which can also be reintroduced into the process.

Evaluation

The quantity of defective pieces generated will depend on the type of installation, but it can reach a figure of up to 1 % of the plant's total production. This system results in a double saving, as the leftover material is reused as raw material, and a product that can be reused need no longer be handled as waste.

The following series of images shows a practical example of this process.

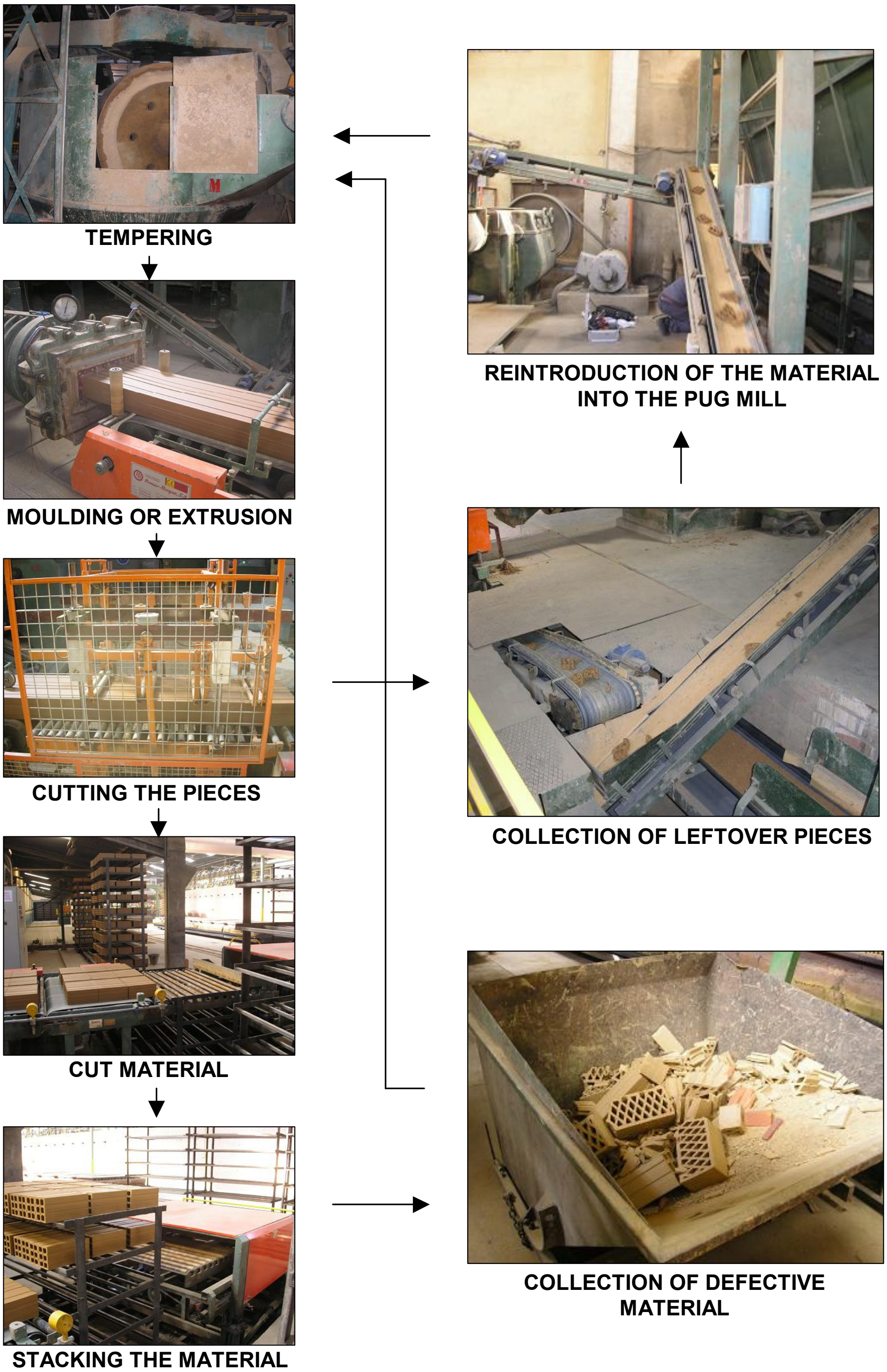


Figure 7.1: Diagram showing the reuse of defective material before firing

7.5. USE OF HOT GASES FROM THE KILN FOR THE DRYING PROCESS

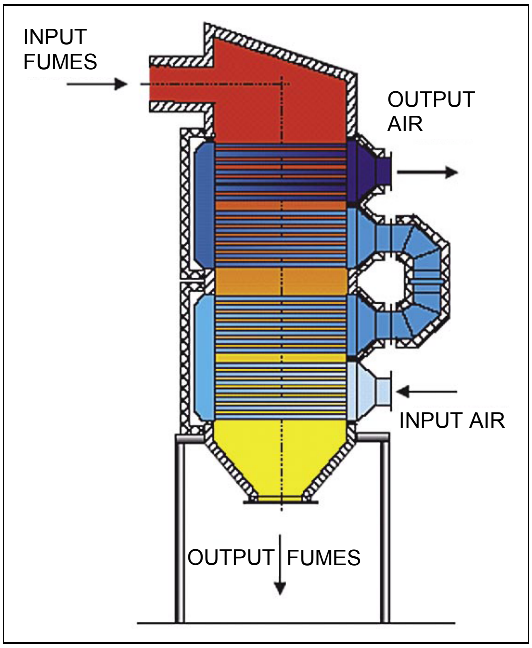
Background

In some installations in the sector, the process of drying the material prior to its entry into the kiln (see Section 3.5 of this manual) takes place by means of the installation of burners that consume fuel (natural gas, biomass or others) in order to heat the air. As a result, emissions into the air of combustion gases, particles, etc. are generated in greater or lesser proportions according to the fuel that is used.

The installation of a system that allows hot gases from the kiln to be used can reduce and even entirely remove the need for fuel consumption for drying.

Description

The system is formed by a pipeline connecting the two installations, together with a system of hot air ventilation (regenerator), which transports the hot air to the interior of the dryer. Once the air is inside the dryer, it is redistributed by the fans in the dryer's interior.



Source: Autonomous Government of Andalusia

Figure 7.2: Kiln gas heat regeneration apparatus

The air that is used is free of pollutant loads, as it is collected in the final area of the kiln and the main emissions are produced in the central area and are sucked in and emitted into the air through a point source (which should contain a filter to ensure the lowest possible emission of pollutants).

This image shows an example of the use of gases from the kiln to dry the material before it is fired

Image 7.3: Using gases from the firing kiln

The use of this residual heat can also be employed for:

a) Pre-heating and pre-drying of the material fed into the prekiln (if there is one).

c) Pre-heating of the combustion air (by means of indirect exchange).

Depending on the type of kiln and its system of operation, the average temperature of the direct regeneration of heat from the kiln (hot air), varies between 150 – 200 ºC and 275 – 385 ºC. This means that the kiln-dryer connection (heat regeneration) enables the overall consumption of the group of equipment to be reduced. Depending on the type of kiln and dryer and their systems of operation, the temperature of the air pumped into the dryer from the mixing chamber varies between 100 and 150 ºC for tunnel kilns, and between 70 and 90 ºC for Hoffmann kilns.

In addition to this, it should be noted that in tunnel kilns there is residual heat that is sufficiently hot to be reused in the process. For example, the heat from the refrigeration of the vaults and the kiln cars is outputted as an air current at a temperature of 100-120 ºC, which can be used in the prekiln (if there is one) or in the mixing chamber itself, by mixing it with the air from direct regeneration, or by using it as combustion air in the kiln nozzles.

Evaluation

The implementation of this system will result in a reduction in the overall emissions of the company by a percentage that will depend on the type of fuel used in the dryer.

The expected savings vary between 2 and 6 % of the overall consumption of the kiln as a result of the use of gases from the kiln, and of around 1-5 % of the overall consumption of the kiln as a result of the recovery of waste heat.

7.6. SWITCH TO COGENERATION

Background

The consumption of electricity in the industries of the industrial ceramics sector is considerable, due to the machinery involved in the different processes. An important means of improving this consumption is to switch to cogeneration in the plant for the generation of electricity, so that part of this is channelled off into the grid and part is consumed by the company itself. Moreover, the waste heat that is produced by this can be used in the manufacturing process itself.

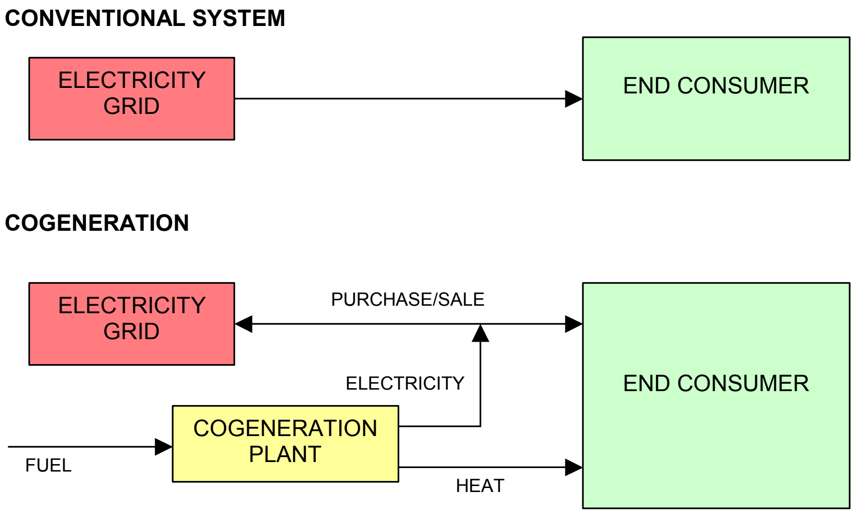


Figure 7.3: Conventional system vs. cogeneration

Description

In companies producing ceramics, the demand for usable heat can be satisfied by using cogeneration in the following ways:

- Hot air for the dryer (of between approximately 100 and 120 ºC).
- Air or combustion gases for the requirements of the prekiln.
- Steam for tempering.

There are different types of cogeneration that have different characteristics. The table below shows the main advantages and disadvantages of each of the types:

Table 7.4: Main advantages and disadvantages of the different types of cogeneration

TYPE	ADVANTAGES	DISADVANTAGES
GAS TURBINE	• Wide range of applications • Highly reliable • High temperature of the heat energy • Range from 0.5 to 100 MW • Gases with a high oxygen content	• Limitation in the fuels used • Relatively short lifespan
STEAM TURBINE	• Very high overall output • Extremely safe • The possibility exists for the use of all types of fuels • Long usable lifespan • Wide range of powers	• High electrical power cannot be attained • Slow to start up • High cost
RECIPROCATING ENGINE	• High electricity output • Low cost • Long lifespan • Capacity to adapt to variations in demand	• High maintenance costs • Heat energy obtained is of a low temperature

Evaluation

As mentioned above, cogeneration enables the energy needs of the plant to be met at a lower cost than that of a conventional system.

The economic saving that is made depends on the difference between the price of the electrical energy obtained directly from the grid and the price of the fuel used in the plant. In cases where some excess electrical energy is sold to the grid, it will also depend on the margin between the price of the fuel used and the sale price of the energy.

The greater that this difference is, the greater the benefit that is obtained, and as a result, the more quickly the installation is amortised.

Normal applications of cogeneration generally result in reductions of 20-30 % of the energy bill, with amortisation periods of the investment of the order of 2 to 3 years.

7.7. INSTALLATION OF HIGH-SPEED BURNERS IN THE KILN

Background

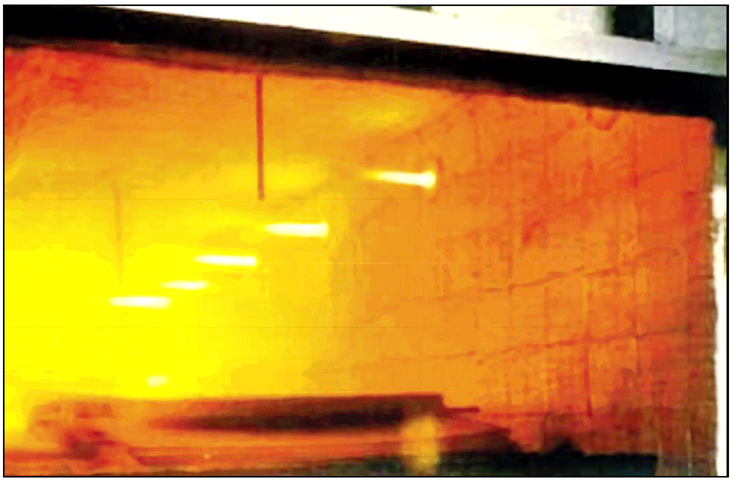
The consumption of heat energy by the ceramics sector is one of the most significant aspects. For example, the average cost of heat energy used by a plant producing 50,000 t/year can account for 25 % of the company's total costs.

A large part of this heat energy is consumed within the kiln and in many cases in the dryer.

Description

The fitting of high-speed burners in the side walls of the pre-heating zone of a tunnel kiln enables greater homogeneity to be obtained of the temperatures in the upper and lower parts of the packets of bricks. This ensures that the firing of the material is quicker and more effective.

The following image shows the line of high-speed burners in the side walls of a tunnel kiln.



Source: Autonomous Government of Andalusia

Image 7.4: High-speed burners in a tunnel kiln

Evaluation

The installation of this type of burner results in a reduction of both the length of the firing cycle (with the consequent increase in productivity of between 20 and 30 %) and the kiln's specific consumption level (by approximately 5 %).

7.8. INSTALLATION OF A LOW-CONSUMPTION LIGHTING SYSTEM

Background

The electrical consumption of the plant's lighting system is often overlooked; nevertheless, it is an important element to take into consideration for the reduction of the company's overall energy consumption.

Description

As mentioned above, this system includes 2 aspects:

- The introduction of **electronic ballast switches** in fluorescent lights operating with starter switches**.**

  The aim of the ballast is to stabilise the charge in the interior of the fluorescent tube, thus ensuring that the lamp operates correctly and that it lasts for the appropriate amount of time.

  In addition to this, by increasing the operational frequency of the fluorescent tube, its lighting efficiency is increased. For example, if the frequency is increased to over 15 kHz, keeping the power constant, the flow of light increases by approximately 10 %.

- The substitution of mercury vapour lamps with **high-pressure sodium vapour** lamps (the following table classifies some types of lamps available together with their performance).

Table 7.5: The most widely used types of lamp

TYPE	INTENSITY (LUMENS)	CONSUMPTION (W)	AVERAGE LIFESPAN (H)	PERFORMANCE (LUMENS/W)
High pressure sodium vapour	6,500	70	24,000	78.3
Mercury vapour and metallic halogen	5,200	70	8,000	59.3
Mercury vapour	6,500	125	18,000	47.4
Quartz iodine, halogen	5,000	300	1,500	16.6
Incandescent	4,800	300	1,000	16

The following image shows a diagram of a sodium vapour lamp with a clear outer bulb and another with a diffusing outer bulb.

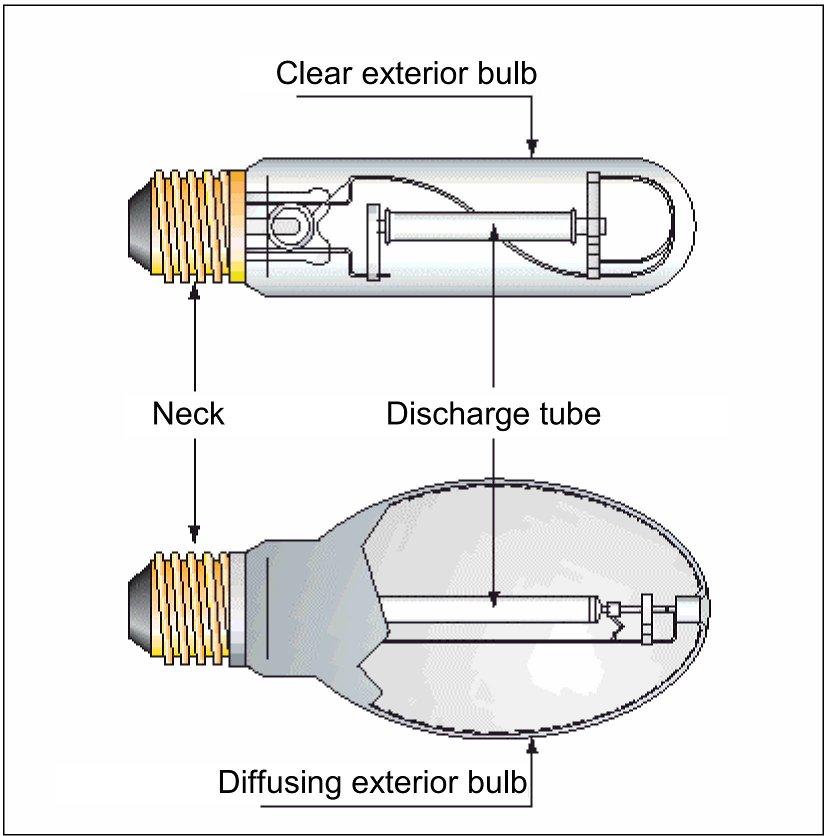


Image 7.5: High-pressure sodium vapour lamps

Evaluation

The installation of electronic ballast can result in a saving of over 25 % of the consumption of conventional lighting.

In addition to this, the investment needed to substitute a 250 W mercury vapour lamp with a 150 W sodium vapour lamp that operates for over 4,000 h/year with electricity costs of 8.42 €/kWh can be amortised in a period of under a year and a half.

7.9. INSTALLATION OF ENCLOSURES TO REDUCE NOISE EMISSIONS

Background

The grinding process that is carried out during the manufacturing of ceramic products generates a significant amount of noise due to the crushing of the clay. This noise will be more or less significant depending on the type of machinery involved and on the characteristics of the clay. Whatever these may be, external noise may be generated and therefore the levels reached may be above those permitted by regulations that are applicable in the zone in which the installation is situated. (These will be more or less restrictive depending on whether the company is located in an urban zone or an industrial zone).

Description

The following graph compares the result obtained by the application of corrective noise-reduction measures, including the installation of a system of soundproofed enclosures. This system noticeably reduces noise at medium and high frequencies.

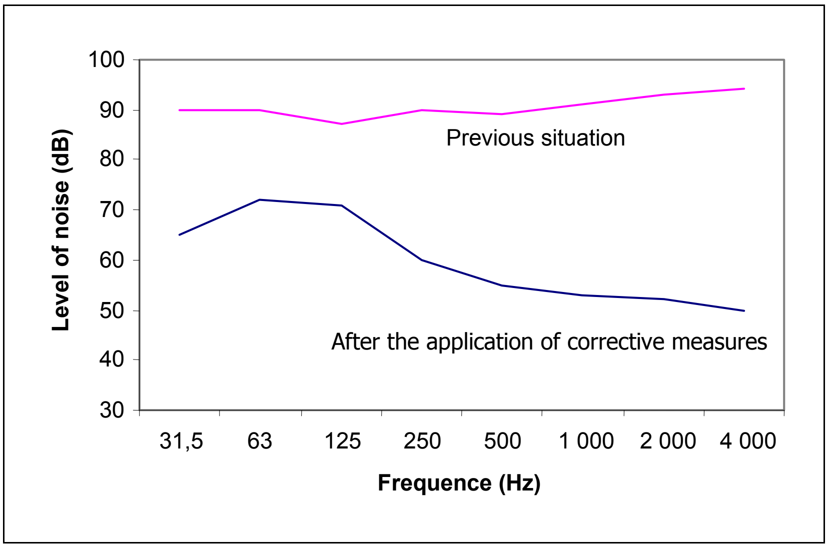


Figure 7.4: Comparison of noise emissions with and without corrective measures

Evaluation

The application of this type of corrective measures enables the level of noise from machinery to be reduced considerably, thus fulfilling the requirements of applicable legislation. This system can also be applied to other types of technology with similar characteristics, such as cogeneration motors.

7.10. INSTALLATION OF HIGH-PERFORMANCE MOTORS

Background

In companies that operate in the structural ceramics sector, high-power motors (in general above 100 and 200 HP) that consume large amounts of electrical energy are usually used.

Description

A high performance electric motor has a longer useful lifespan than a conventional motor, and its cost is around 5 to 25 % higher.

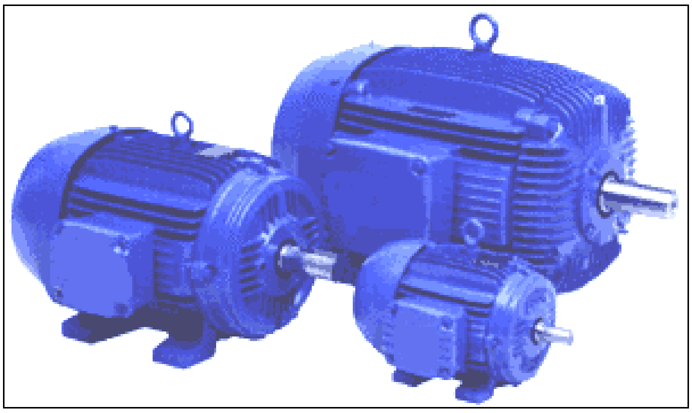


Image 7.6: High-performance motors

Evaluation

Taking only the electricity saved by the use of the motor into account, the amortisation period for the replacement of a conventional motor with a high-performance motor would be too long. However, taking only the extra cost of the equipment into account, the amortisation period is reduced to 1 or 2 years. This means that this type of change is effective from all perspectives in new installations or when it is necessary to renew motors in existing installations when they have reached the end of their useful lifespan or because a major breakdown has occurred.

8. SUMMARY AND CONCLUSIONS

Of the 20 countries of the Mediterranean region analysed in this manual, the main producers of structural ceramics are Italy and Spain (with a total of 30 % of the global market) followed by Turkey and France, which lag considerably behind. This fact is due to a great extent, to the strong growth in the construction sector in the former two countries, as the structural ceramics sector is closely linked to the evolution of economic cycles and to the activity of the construction industry.

Companies generally set up in close proximity to the site from which their raw materials are obtained and near to centres of consumption, in order to minimise the transport costs of their products, which already have low added value. As a result, many installations can be found that have their own quarry from which clay, used as the main raw material, is extracted.

The production process is characterised by the fact that it is fairly similar in all of the countries studied, and only vary in terms of the technology used. Broadly speaking, the main processes involved in the manufacture of structural ceramics materials are the following:

1. Receipt and storage of raw materials
2. Grinding
3. Shaping (including tempering and moulding)
4. Drying
5. Firing
6. Preparation of raw materials

If each of the processes is studied in depth, it can be seen that a considerable amount of electricity is consumed due to the amount of machinery involved. This consumption is covered in many companies by cogeneration, which leads to a financial saving for the company and to the improved optimisation of the fuel used, as it enables the heat energy generated to be used in the process (see Pollution Prevention Opportunity 0-16).

Processes 4 and 5, which correspond to the firing and drying processes, are the processes in which the main environmental impacts caused by the structural ceramics sector are generated.

A significant amount of fuel is used in the kiln and often also in the dryer, which on the one hand generates emissions that are piped into the air, as a result of combustion, and on the other, causes diffuse emissions into the environment due to storage (depending on the type of fuel).

As a result, the type of fuel used by the company and the way in which it is used are two key aspects in the sector in terms of resulting in greater or lesser environmental impact. Given the importance of this fact, in Chapter 5 a description is provided of the main fuels used in the sector, together with a comparison of these, analysing their respective advantages and disadvantages.

If the fuels studied in the manual are placed in order according to the amount of emissions generated that are piped into the air (from less to more) the results are as follows:

1. Natural gas
2. Biomass
3. Petroleum coke
4. Fuel oil
5. Coal

The substitution of one fuel for another is often not possible for a company due to the high investment that this would require. Nevertheless, the process can be optimised for each of the five fuels listed, so that the impact caused is as low as possible.

It is clear that one of the most important environmental impacts of the sector is energy consumption, and therefore an important part of the opportunities included in Chapter 6 are aimed at improving energy yield:

- 0-11: The control of losses in hydraulic and water circuits
- 0-13: The use of hot gases from the kiln for the drying process
- 0-16: The use of cogeneration to generate steam
- 0-17: The installation of natural gas consumption meters
- 0-18: The installation of high-speed burners for kiln preheating
- 0-20: The use of a low-consumption lighting system
- 0-22: Improved air distribution in the dryers
- 0-23: The substitution of motors with high performance motors
- 0-24: The use of stiff extrusion

On the other hand, the structural ceramics sector is characterised by its moderate water consumption, which in addition generates no process wastewaters, as for the most part the water used is absorbed by the clay during tempering.

Lastly, as in any industrial activity, an important amount of hazardous and non-hazardous waste is generated, and wherever possible this should be avoided at source, or if this is not possible, it should be managed correctly.

As it is one of the most important sources of waste, the generation of defective fired products should be highlighted. This can make up a considerable percentage of the plant's total production, and hence its reduction at source can result in a saving in its final management, together with increased production.

The opportunities for pollution prevention outlined in this manual (Chapter 6) show that this is a sector that can improve the impact it has on the environment through actions that do not require high levels of investment, and that in many cases can be classed as good practices resulting from a change in habits.

However, also included here are opportunities for improvement that require a more significant investment on the part of the company, and which involve a change to more efficient technology. These improvements can be introduced by the company for different reasons, such as breakdowns, increases in production, optimisation of resources, etc.

The application of the IPPC Directive 96/61/EC within the framework of the European Union is a clear move towards reduction at source based on best available techniques (BAT). To this end, the opportunities outlined in this manual that involve significant investment are intended to encourage this philosophy, and serve as a challenge for companies in the structural ceramics sector that want to take a technological step forward. For those companies that are located outside the legal framework of the European Union, this document can serve as an important point of reference in terms of orientation for new investments, and as a clear opportunity to stand out from the competition nationally or internationally.

However, it is advisable to carry out a study to verify which options are recommendable for each specific case, depending on the characteristics of the company and the country in which it is located.

The increasing requirements of environmental regulations and legislation, together with the growing awareness of the population in general with regard to the need to protect the environment have meant that society demands greater respect from the environment from companies in their production processes. All of these points make it necessary for companies to include aspects related to environmental protection within their production management. The innovation necessary to meet the new challenges of the market can, at the same time, serve as an opportunity for companies within the structural ceramics sector to improve their levels of environmental impact.

9. BIBLIOGRAPHY

Main bibliographical sources

- **European Commission.** Draft reference Document on Best Available Techniques in the Ceramics Manufacturing Industry (2004)
- **EPA.** Brick And Structural Clay Product Manufacturing (1997)
- **IHOBE.** Guía de notificación de emisiones para el sector de productos cerámicos (2003)
- **Institute for Regional Development**. Estudio Medioambiental del sector de los materiales (1999)
- **Autonomous Government of Andalusia.** Guía de notificación de las emisiones de la industria de fabricación de elementos de construcción (2005)
- **Autonomous Government of Andalusia.** Industria de la cerámica estructural (2003)
- **Ministry of Industry and Energy.** Guías tecnológicas: Fabricación de materiales cerámicos de construcción (1996)
- **Ministry of the Economy.** Estrategia de ahorro y eficiencia energética en España 2004-2012. Subsector minerales no metálicos (2003)
- **Técnica Cerámica journal.** A number of editions published between 2000 and 2005

Main websites visited

Albania

- Trade and Tourism Office of Albania: www.promoalbania.org

Algeria

- Spanish Embassy in Algeria: www.tsai.es
- Office for the Promotion of Foreign Trade in Algeria: www.eldjazair.net.dz
- Algerian National Office of Statistics: www.ons.dz
- Algerian National Office of Statistics: www.inapi.org

Bosnia-Herzegovina

- Foreign Trade Chamber of Bosnia and Herzegovina: www.komorabih.com
- Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina: www.mvteo.gov.ba
- Chamber of Economy of the Federation of Bosnia and Herzegovina: www.kfbih.com
- Agency for Statistics of Bosnia and Herzegovina: www.bhas.ba/flash/eng/index/index.htm

Croatia

- Ministry of Economy, Labour and Entrepreneurship of Croatia: www.mingo.hr
- Ministry of the Sea, Tourism, Transport and Development of Croatia: www.mpv.hr
- Ministry of Environmental Protection, Physical Planning and Construction of Croatia: www.mzopu.hr

Cyprus

- Department of Statistical Information of Cyprus: www.pio.gov.cy/dsr
- Government-Administration of Cyprus: www.cypirus.gov.cv
- Important portal for Cyprus: www.kypros.org
- Central Bank of Cyprus: www.centralbank.gov.cy
- Cyprus Chamber of Commerce and Industry www.cci.org.cy
- Statistical Service of the Republic of Cyprus: www.pio.gov.cy/dsr/index.html

Egypt

- Government portal of general information on Egypt: www.highway.idsc.gov.eq
- Governmental portal providing information on the current situation in Egypt: www.idsc.gov.eq
- Ministry of Foreign Affairs of Egypt: www.mfa.gov.eq
- Ministry of Trade and Industry of Egypt: www.economy.gov.eq
- Portal of economic analyses and studies of trade matters of importance to the Egyptian economy: www.economy.gov.eq/depra/
- Portal of information on the situation of the privatisation process in Egypt: www.egytinc.com
- General information on the Middle East: www.middleeasttimes.com
- Egyptian economic publications: www.meed.com
- Periodical on the economic situation in Egypt: www.egyptinc.com/egyptinc_frame1.htm

France

- French Chamber of Commerce in Spain: www.lachambre.es
- French Embassy in Spain: www.ambfrance-es.org
- French Agency for International Business Development: www.cfce.fr
- French National Institute for Statistics and Economic Studies: www.insee.fr
- UBIFRANCE (French information service): www.cfce.fr
- French International Chamber of Commerce: www.iccwbo.org
- Chamber of Commerce and Industry of Paris: www.ccip.fr
- French Ministry of the Economic and Treasury: www.finances.gouv.fr
- Chamber of Commerce of Paris: www.ccip.fr

Greece

- Hellenic Foreign Trade Board: www.hepo.gr
- National Statistical Service of Greece: www.statistics.gr/Main-eng.asp

Italy

- Italian National Association of Constructors: www.ance.it
- Association of Producers of Ceramics and Refractory Materials of Italy: www.assopiastrelle.it
- Various associations in the construction sector in Italy: www.buildinginitaly.com/associazioni.asp
- Italian Chambers of Commerce: http://www.camcom.it/
- Confederation of Italian Industry: http://www.cofindustria.it/
- Institute of Construction Research in Italy: http://www.cresme.it/
- Reference portal of construction in Italy: http://www.edilio.it/
- Federation of Construction Material Traders in Italy: http://www.federcomated.it/
- European Federation of the Construction Industry in Italy: http://www.federcomated.it/
- Ceramic World Web (digital journal of the ceramics sector in Italy): www.ceramicworldweb.it
- Tile Italia (digital journal of the ceramics sector in Italy): www.tileitalia.it

Slovenia

- Chamber of Commerce and Industry of Slovenia: www.gzs.si
- Ministry of the Economy of Slovenia: www.gov.si.mq-rs.si
- Government of Slovenia: www.gov.si
- Ministry of Foreign Affairs of Slovenia: www.gov.si/mzz
- Statistical Office of Slovenia: www.stat.si

Spain

- Association of Ceramic Tile Manufacturers of Spain: www.ascer.es
- Institute of Foreign Trade: www.icex.es
- Market Access Database: http://mkaccdb.eu.int
- National Federation of Commercial Agents: www.comagent.com
- Chamber of Commerce of France: www.coef.com
- Spanish Embassy in France: www.amb-espagne.fr
- Spanish Association of Brick and Tile Manufacturers: www.hispalyt.es
- Association of Construction Materials Traders (Spain): www.asemaco.es
- Spanish Confederation of Associations of Construction Product Manufacturers: www.cepco.es
- Journal of the ceramics, brick and roof tile sector in Spain: www.publica.es/publica/p-tc.html
- Association of construction companies at a national level (Spain): www.seopan.es

Other sources consulted

Israel

- Federation of Israeli Chambers of Commerce
- The Israel export & International Cooperation Institute

Lebanon

- Lebanese Central Bank
- Chamber of Commerce, Industry and Agriculture
- Ministry of Economy and Trade
- Ministry of Industry of Lebanon

Lybia

- Tripoli Chamber of Commerce, Industry and Agriculture
- Federation of Chambers of Commerce, Industry and Agriculture

Malta

- Central Bank of Malta
- Statistics on international trade
- Chamber of Commerce of Malta

Morocco

- Basic guide to the Moroccan market
- Ministry of Foreign Trade
- Ministry of Industry and Trade of Morocco

Syria

- Ministry of Economy and Trade of Syria

Turkey

- Turkish Ministry of Industry, Tourism and Trade
- Central Bank of Turkey
- Institute of Statistics of Turkey
- International trade statistics

Others

- Market research from the Economic and Trade Offices of the Spanish Embassies in the Mediterranean countries
- Country guides and data sheets. *ICEX (Spanish Institute of Foreign Trade)*
- Economic and Trade Reports of the Mediterranean countries. *ICEX (Spanish Institute of Foreign Trade)*
- Market access database

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