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**CURRENT AND FUTURE CHALLENGES OF THE
CERAMIC TILE FIRMS**

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1. INTRODUCTION

The Spanish ceramics sector is one of the main industries in the country with a long tradition and experience in the production of all types of ceramic products, from tiles to construction and decoration elements. This has allowed it to be one of the main producers of ceramics in the world, having an important presence in the national and international market, with its products being recognised for their quality, innovation and design.

The aim of this work is to analyse the Spanish ceramics sector, its characteristics and the technological innovations that have been applied in it in recent years, in order to analyse how the Spanish ceramics industry can apply technological innovations to improve the quality of its products and reduce its environmental impact. To this end, aspects such as the manufacture of tiles and floor tiles will be addressed, as well as their environmental impact and consumption trends in the national and international market.

In this study on the ceramic sector we have focused on the current and future challenges of the Spanish ceramic industry because it is a predominant sector in the province of Castellón de la Plana, forming the most important ceramic cluster in Spain. The Spanish ceramic cluster is one of the most competitive and innovative, being one of the world leaders and providing quality employment to many people.

Therefore, in this report we will focus on studying the technological innovations applied in the Spanish ceramic cluster, in order to understand the importance for companies to adapt and carry out changes, through innovations, which allows them to obtain better positioning in the markets they operate in.

It is also worth highlighting how the organisations that make up the cluster try to take advantage of available resources and growth opportunities to keep up with competition and technological advances.

First of all, we will focus on a detailed description of the ceramic sector, its history, evolution and importance for the Spanish economy. We will analyse the main characteristics of the sector, such as its size, the diversity of products and services it offers, its capacity for innovation and its adaptation to market changes. In addition, we will examine the main relevant stakeholders in the sector and their geographical distribution.

On the other hand, we will address the technological innovations that have been applied in the ceramics sector in recent years. We will describe the latest trends in machinery, materials and production processes, as well as the new solutions that have been developed to improve quality, energy efficiency and sustainability in the sector. We will also analyse the advances in the digitalisation and automation of production processes, which are enabling greater precision and speed in production.

Finally, we will study the challenges and opportunities for the ceramics sector in the current context, analysing the environmental challenges and consumption trends, as well as the public and private policies and strategies that are being implemented to boost the growth and competitiveness of the sector. Focusing above all on the business opportunities in the national and international market and the future prospects of the sector.

In short, the aim of this work is to offer a complete and updated vision of the Spanish ceramics sector, its characteristics and the technological innovations that have been applied in it.

With this work we aim to contribute to a better understanding of the economic, social and environmental importance of the sector and the challenges and opportunities that arise in the current context.

2. THEORETICAL FRAMEWORK

Within the theoretical framework, we are going to carry out a theoretical analysis of all the concepts that we will deal with during the work. Therefore, before drafting the report, we will analyse how the ceramics cluster and environmental strategies work. In this analysis, we see it convenient to explain the concepts of cluster and innovation and then focus on the concept of green or environmental innovation.

Through this analysis, we will be able to understand theoretically the aspects that we will cover in the report, which will serve as a basis throughout the report.

2.1. THE INDUSTRIAL CLUSTER

First of all, we are going to analyse the concept of cluster, because it is an important concept when describing the Spanish ceramic cluster, which we will analyse later on.

Before going deeper into the concept of cluster, I would like to explain what agglomeration economies, later known as clusters, are. The concept of agglomeration (Porter, 1991) is given by a concentration of firms which take advantage of externalities and achieve economies of scale and lower transaction costs due to the proximity relationships between firms.

Having defined the concept of agglomeration economies, we will analyse the concept of clusters. A cluster is a set of firms specialised in a certain activity, forming an integrated whole, whose dynamics are shaped by a constant feedback loop.

So now we need to explain the term cluster and all the aspects that affect it. First of all, we will consider different definitions of the cluster concept by different authors, but above all we will focus on Porter, as he was the first author to disseminate the concept of industrial district in the nineties.

2.1.1. CLUSTER CONCEPT

Cluster analysis goes beyond traditional economic sectoral approaches and cost reduction due to proximity of factors. For this reason, we understand that the cluster concept has different theoretical roots, which we will now look at from different authors and perspectives to better understand this concept.

Porter (1991) in his book *The Competitive Advantage of Nations* defines a cluster as a group of geographically connected industries that are linked by common and complementary characteristics to other related entities in a particular field.

On the other hand, Gordon & McCann (2000) defined the concept of cluster based on the conclusions drawn by Marshall in the concept of agglomeration economies, for which they defined a cluster as an industrial complex formed by the aggregation of companies through a network model, in the sense that economic and business productivity is affected by location and distance.

Finally, research by the Organization for Economic Co-operation and Development (OECD, 1999) postulates that clusters are characterised by economic networks in which independent firms are closely linked in value-added production chains.

Therefore, having defined the different perspectives on the concept of cluster by different authors, we will focus on Porter's definition, in order to define the concept of cluster on his research.

In his research Porter (1990) he uses the concept of the competitiveness diamond, which establishes four general attributes that contribute to an organisation's ability to achieve a competitive advantage over others. His research establishes the following aspects:

- Factor conditions:

Factor conditions determine a country's position in terms of factors of production, which will be necessary to compete in a particular industry.

Factors of production include labour, natural resources, capital and infrastructure, all of which will be important determinants of trade. In addition, these factors include efficiency, responsiveness and the relationship that the firm has established with its environment creating a greater competitive advantage for the firm when these factors are more difficult for its competitors to imitate. (Krugman, 1980)

Therefore, companies must identify the basic, generic, advanced and specialised factors of production in order to position themselves in the market and create competitive advantages.

- Demand conditions:

Porter's theory states that the nature of domestic market demand for products or services has an indirect influence when seeking competitive advantage, as demanding and informed consumer groups will influence companies to make improvements or investments to satisfy their demands, thus differentiating their processes from those of their competitors.

In other words, companies should innovate whenever possible and look for new strategies that allow them to anticipate the possible needs of customers, enabling companies to be more competitive. (Porter & Linde, 1995)

- Strategy, structure and competition between companies:

Competitors are another element that favours the emergence of competitive advantages in the business environment.

As a result of competition between industries or markets, an effect is generated that makes companies need to improve their offerings or the quality of their products, developing new approaches that allow them to improve their processes and thus gain competitive advantages.

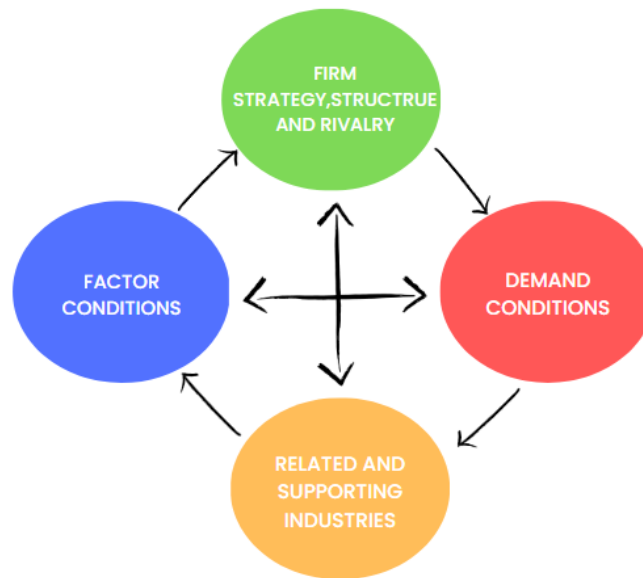
Additionally, this stimulus gives the possibility of generating an internal stimulus that favours internal competition, boosting internal productivity and performance. (Porter, 1980)

- Related and ancillary sectors:

This factor is of an internal nature and nations place more value on it than companies. Because it is an element that refers to the intense competition between some economic sectors, which in turn raises the supply and makes them profit in the international market with respect to their competitors.

We can then interpret related sectors as the potential for competition between the members of an industry that allows it to achieve specific production margins due to a coordination of resources between different nearby companies that favour the exchange of information, creating synergies and favouring competitive advantages. (Saxenian, 1994)

Figure 1: Determinants of Competitive Advantage Porter's Model



Source: Porter, 1990

These attributes set the environment in which companies compete. Each attribute that makes up the diamond and the diamond as a system will mark the competitive success of firms.

In addition to these elements, Porter (1990), in his competitive advantage diamond, introduced two additional components that, although they do not directly affect the development of competitive advantage, play a very important role in achieving it. We will now describe the importance of these additional elements within the diamond:

- Azar:

Porter gives importance to chance in his discussion of competitiveness. He believes it is important to take into account unpredictable events, which have the potential to create discontinuities. Although it is a factor that is not reflected in the diamond, it is a factor that must be taken into account as it can create asymmetric effects.

- Government:

In order to create a competitive advantage, we must take into account the resource management model. For, if we refer to countries, the government plays an important role in determining positively or negatively the course of the factors of Porter's diamond

because, through legislation, it will establish measures that can affect the markets in which companies operate.

2.1.2. CLUSTER INFLUENCING FACTORS

After observing how Porter (1990) identifies the different components that form the competitive advantage diamond, it is convenient to identify the different factors that influence the cluster. Therefore, in this analysis we will take into account both the factors that influence internally and externally, in order to obtain which are the success factors for the companies that make up the cluster.

The first factor that we are going to analyse are the public entities, which are organisations that carry out functions aimed at establishing control for compliance with standards or helping to obtain best practices.

The second factor we will consider is the companies, which is one of the most influential factors. Companies operating in a cluster have similar working operations which, together with the proximity between them, makes them share resources, favouring interaction and knowledge between companies.

In this way, companies can obtain a better business vision that improves competitiveness among them and favours innovation, positively affecting the productivity and performance of the companies. (Krugman,1980)

So in a cluster we can observe that there are different types of companies, from companies that are devoted to the main production of the cluster, to other related companies devoted to obtaining raw materials, companies specialised in machinery, companies in charge of elaborating materials that are used for the final production, among many other companies that may form the cluster.

On the other hand, the third factor that we are going to analyse is the labour market, which refers to the set of human resources available to carry out any type of activity within the cluster.

This factor is very important and indispensable because all the organisations that form the cluster are composed of individuals, and the efforts of these individuals will determine the success or failure of an organisation. (Porter,1985)

Finally, we will analyse the financial market which allows companies to obtain financing to create and carry out their processes, to sell and buy products and to make investments.

2.1.3. TYPES OF CLUSTERS

In order to understand what a cluster is, we must take into account the types of clusters that exist, emphasising each one in order to understand what functions are performed or how they are generated.

First of all, we will describe the cluster according to which companies are linked to the industries that compose it, we can distinguish two types of clusters:

- Vertically integrated cluster:

Through vertical integration, companies are linked through supply chains. That is, in a cluster there may be companies that make batteries for mobile phones and others that make the computer system.

- Horizontally integrated cluster:

A horizontally integrated cluster allows organisations to share common knowledge in the same market where they produce similar products. That is, they use similar technology, human and natural resources.

Therefore, a horizontally integrated cluster is composed of competing firms that distribute similar products.

Although we have seen the two types of clusters that exist according to the association between industries, there are four different types of clusters that we will now analyse. (Porter, 1995)

- Industrial Cluster:

An industrial cluster refers to a geographic concentration of related firms and organisations in a specific industry, which mutually benefit from sharing resources, knowledge and collaborating in related activities. According to Professor Michael Porter (1990), an industrial cluster is a "geographic group of interconnected firms and specialised suppliers, which compete but also cooperate".

In other words, industrial companies that are engaged in the production and distribution of products while maintaining a direct relationship with stakeholders.

- Value chain cluster:

The value chain cluster is a geographical grouping of interconnected companies and institutions along a specific industry or economic sector. It consists of a set of companies that are related to each other by buying and selling goods or services, maintaining a geographical proximity between suppliers and buyers. This proximity allows them to reduce costs and better match supply and demand.

In other words, these clusters promote collaboration, specialisation and competitiveness, with the aim of boosting economic growth and innovation in the sector.

- Technology cluster:

Technology clusters are groups of companies related to the technology sector, with the aim of fostering collaboration, innovation and growth in the field of technology through research centres or universities. These clusters facilitate interaction between actors in the technology ecosystem and promote the development of innovative solutions and services. (Saxenian, 1994)

Factor endowment cluster:

These are partnerships between companies to gain comparative advantages, to be able to connect with specific geographical elements, as in the case of the California wine cluster.

In conclusion, we can state that in the past, governments chose to promote the growth of specific clusters. However, over time it has been proposed that a cluster approach may be more successful because it focuses on systems rather than businesses (Gil & Lopez, 2020).

For this reason, one of the major benefits of a cluster is the diversity of actors that support and promote it and play a crucial role in its growth (Manene, 2014).

2.1.4. BENEFITS OF BEING PART OF A CLUSTER

Once we have defined what a cluster is, the types of clusters and the factors that influence cluster development, we will identify the associated benefits of being part of the cluster.

In terms of the key factors that influence the performance of a cluster, we will highlight the following:

1. Competitive Intensity

To determine the level of competitive intensity, a set of economic attributes and technologies has been used to describe the circumstances of each of the competitive forces at a given point in time. Porter (1980) identified the following competitive forces.

- *Rivalry between competing companies*: Rivalry between firms in the cluster causes them to seek a competitive advantage over the strategies of rival firms. This enables firms to invest more in technology, R&D and creativity to gain a better position in the cluster.
- *Potential entry of new competitors*: The entry of new companies into the market increases existing production capacity in the sector, leading to increased rivalry and the need for information which can lead to companies communicating to exchange important information and develop their products and businesses.
- *Potential development of substitute products*: Companies in the cluster join forces to compete with companies that market substitute products, so that by working together they can take advantage of economies of scale and obtain a better positioning than industries that manufacture substitute products.
- *Bargaining power of suppliers*: The bargaining power of suppliers is a crucial factor affecting the level of competition in an industry. This power becomes especially relevant when there are a large number of suppliers, shortages of alternative raw materials or high costs associated with switching to other raw materials. Because of this, companies within a cluster seek to establish agreements with suppliers in order to gain competitive advantages.
- *Bargaining power of customers*: The bargaining position of customers is a significant factor in determining the level of competitiveness in a market.

2. Institutions:

Both private and public institutions provide collective support to the cluster companies such as vocational training institutions, research institutes, universities, technical assistance organisations, related companies and professionals.

All these associations, which are part of and support the cluster, serve to improve the cluster's industrial and technological policy, both through financial support and by providing information on innovation and development issues.

3. Business cooperation:

According to Rodríguez (2006), business cooperation consists of strategic alliances in which a number of independent companies join forces voluntarily to optimise business activity.

From business cooperation arise joint projects between companies, where they join their efforts to carry out a joint project to reduce costs or research new materials that allow them to reduce costs. Organisations can improve their competitiveness and competences through this cooperation.

4. Geographical location:

One factor that affects the success of a cluster is its geographical location because, according to the "Location Theory" (Baena, Sánchez & Montoya, 2008), an activity is better located where costs are lower or in geographical locations where it is more economical to concentrate business.

Therefore, strategic geographic location is important because it allows the development of business linkages, as well as positively influencing the relationships between the companies that form it.

The benefits of belonging to a cluster are many and varied because being part of a cluster is a great resource that allows access to projects of shared interest, identifying market trends and demands and maintaining contact with other companies that have different visions. This allows the company belonging to the cluster to broaden its perspective on the business.

In conclusion, being part of a cluster will bring benefits to the company that belongs to it, but it will have to know how to identify the key characteristics of the elements that make up the cluster to take advantage of them and obtain a competitive advantage.

2.2. INNOVATION

We are now going to analyse the second theoretical concept that we are going to deal with in this paper, green innovation or also known as environmental innovation. But before going into green innovation it is important to define the concept of innovation and its types.

So before defining what innovation is, I would like to emphasise why companies should innovate. Innovation is essential for companies' long-term survival because they operate in a globalised environment, with increasing competition, shorter product life cycles, faster market changes, profound social, economic, political, environmental and technological changes.

Therefore, innovation provides companies with strategic advantages as it stimulates them to reorganise manufacturing processes and make them more effective (Tidd & Bessant, 2018). For example, it will allow them to offer new products or services that competitors will not be able to imitate, offering both financial and non-financial benefits.

2.2.1. DEFINITION OF INNOVATION

In economic, business and social theories, the idea of innovation has been the subject of numerous analyses. The term "innovation" first appeared in Schumpeter's (1997) *Theory of Economic Development*, where the author discusses how innovation generates industry-related phenomena that radically and abruptly change the way the economy functions.

Schumpeter (1997) defined innovation as a process in which new combinations are set in motion to introduce new goods, improve their quality or introduce new methods of production. In other words, Schumpeter understands innovation as the incorporation and subsequent economic and commercial exploitation of knowledge.

After looking at the origin of the concept of innovation, we can see that it is a very broad concept, so we are going to discuss different definitions from various authors to better understand this concept.

According to Van de Ven (1986), the concept of innovation is defined as the creation and application of new concepts by individuals within an organisational environment. On the other hand, Afuah (1998) argues that innovation involves the incorporation of new knowledge into products, processes and organisations.

The OECD Oslo Manual (2005) and Urabe (1988) state that innovation refers to the creation of a new concept and its application in a new good or service, procedure, marketing strategy, organisational practice or method. It is recognised that innovation can manifest itself in different forms, such as goods, services, methods or the very structure of an organisation. Moreover, innovation can be both disruptive and incremental, as Hill (2014) points out.

In short, innovation involves the creation and application of new concepts in an organisational environment. It can manifest itself in the form of new products, processes, methods or even in the structure of an organisation. It can be disruptive, generating radical changes, or incremental, introducing gradual improvements.

Based on the various definitions of the authors, we conclude that innovation is not simply about generating ideas, but involves the creation of new ideas and their subsequent implementation. In other words, innovation is about generating new, valuable and useful ideas and putting them into practice.

In this sense, companies have two options: they can either create their own innovations, such develop completely new products, processes or organisational methods; or they can adopt innovations previously created by other companies or organisations.

2.2.2. SOURCES OF INNOVATION

The sources of innovation allow companies to carry out innovative development, financial or commercial activities that will allow them to invest in new knowledge and obtain new skills. We highlight two sources of innovation, firstly, technology and secondly, the market. Pavitt (1991).

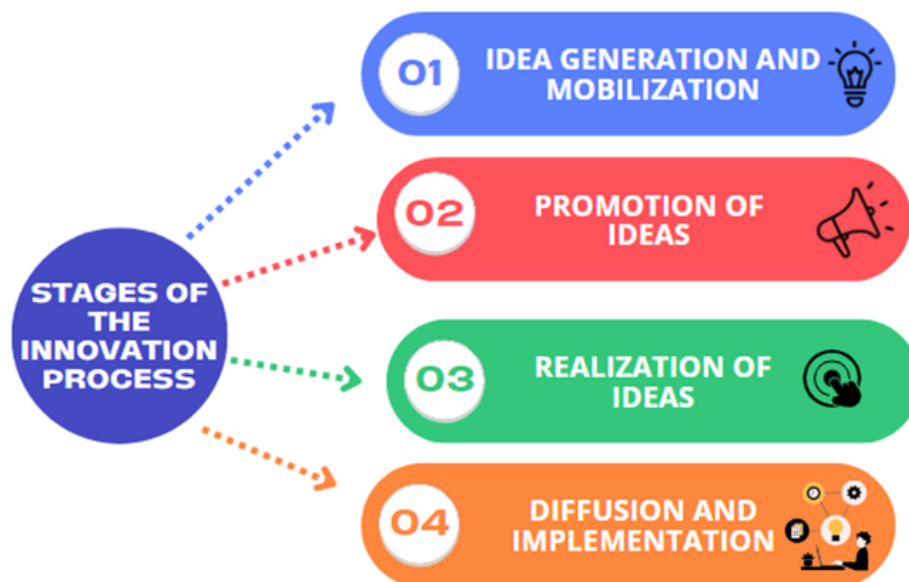
Technology is a source of innovation because through its use we can achieve the development of an idea into a particular good or service, allowing also the improvement of an existing good or service to meet the demands of the market. Some examples we highlight of innovation through technology are artificial intelligence or mobile phones.

On the other hand, we highlight the source of market innovation which can be of different types: innovation of existing product or technology, new product meaning, new users or customers. Therefore, market innovation allows the trends of an industry to change.

In conclusion, we can state that innovation sources are used by companies or groups of companies to encourage the creation and adoption of innovative solutions.

2.2.3 STAGES OF THE INNOVATION PROCESS

Figure 2: Innovation process stages



Source: AE1032 Disseny i Canvi Organitzatiu UJI, Tema 4: Innovaci3n, 2022

- Idea generation

Idea generation is the creation of novel and practical ideas. They usually occur in companies when problems, contradictions or new trends arise.

- Idea promotion

The promotion of ideas arises from the need to seek people's support for the idea you want to implement to ensure that sufficient resources are available to take the idea to the next stage.

- Realisation of ideas

Depending on the type of innovation to be carried out, the idea will be tested at this stage to determine its feasibility.

- Idea implementation

Finally, once it has been studied and verified that the innovation to be carried out is viable, it will be put into practice.

By following these stages, the company will be able to correctly implement the type of innovation it wants to carry out.

2.2.4. TYPES OF INNOVATION

In an effort to standardise thinking around innovation, the European Statistical Office (Eurostat) and the OECD published the *Oslo Manual* in 2005. The *Oslo Manual* lists the following attributes of innovation:

- It is tied to uncertain outcomes.
- Investment in tangible and intangible assets is implicit.
- It requires the application and synthesis of knowledge.
- Its aim is to increase the competitiveness of the company.

After looking at the characteristics contained in the handbook on innovation, we can emphasise that the handbook identifies four types of accepted innovations according to their nature.

- Product innovation

Product innovation could be defined as the introduction of goods or services that have new or improved characteristics. This involves technical improvements, ease of use, the use of new materials and the creation of completely new products. Product innovation plays a key role in the growth and competitiveness of companies, enabling them to offer differentiated products and to meet evolving customer needs. By constantly seeking new ideas and solutions, companies can stay at the forefront of their industry and adapt to market demands. Product innovation is a key factor in generating competitive advantage, increasing market share and achieving long-term sustainable growth.

- Process innovation

The application of new techniques in production processes is what we mean by process innovation. We can implement new methods, tools or software when we carry out process innovation.

- Marketing innovation

The application of novel techniques on product packaging or design to improve product promotion or pricing is a marketing innovation.

- Organisational innovation

The implementation of new approaches to business practices, workplace restructuring or external relations by a firm is known as organisational innovation.

However, Pavitt (1991) distinguishes between two types of innovations depending on their level of novelty. He refers to radical innovations as revolutionary or discontinuous changes and incremental innovations as conventional or direct extensions in a line of historical advances.

Based on existing knowledge and resources, incremental innovation brings about small changes. Thus, incremental innovation suggests improving the procedures or products used, trying to meet existing demands in the current market.

Radical innovation leads to significant changes in performance and requires new knowledge and resources. Thus, it is related to the creation of new products and markets, as well as addressing latent needs. An innovation must be based on novel knowledge or technology to qualify as radical.

In addition, radical innovation must offer consumers a high level of novelty and benefits that amplify the advantages they currently receive from existing goods and services.

Finally, we highlight another type of innovation according to the degree of planning:

Planned innovation is the end result of systematic detection, prioritisation, project structuring, financing, implementation and diffusion of innovation within the organisation.

Unplanned innovation, on the other hand, is a category of innovation that is not planned in advance. It is therefore organised spontaneously and changes can be made to it as it is being implemented.

2.2.5. FOSTERING INNOVATION

Like sales, finance or human resources, innovation is a fundamental business process that can be planned, managed and measured. Procedures and tools now exist to implement innovation as a key business capability. Molina - Morales (2009).

Innovation can then be defined as a process consisting of the development of goods, processes and techniques, which are crucial to make a transition to a cleaner planet. Therefore, it is crucial to emphasise that the term "innovation" does not only refer to technological advances, but can also refer to changes in systems, finance, society and the economy. (OECD, 2019).

Next, we will look at how to encourage the implementation of innovations in organisations.

- Align innovation with company strategy: Companies need a clear understanding of how innovation will help them increase their competitive advantage. Staff may feel that innovation is not the best option. For this not to happen and to be truly effective, innovation must be aligned with the strategic objectives of the business. That is, the organisation should seek to generate new ideas, to increase profits and reduce costs or increase sales.
- Organisation-wide commitment: any change that an organisation wishes to make should be promoted and seen as an overall organisational objective rather than a discrete function.
- Create a communication strategy that reflects and supports the organisation's innovation efforts so that all members cooperate and follow the objectives.
- Establish processes for collecting and evaluating ideas that will allow to understand different points of view and group interesting ideas for further use in the innovation process.
- Create environments or spaces that encourage people's creativity.

It is safe to say that innovation is a process that requires both time and resources to be carried out effectively.

By putting into practice all the principles we have seen above, together with sound strategic planning and a culture that embraces the values of innovation, companies can become more competitive in the environments in which they operate.

2.2.6. BENEFITS

Innovation is undoubtedly one of the key factors contributing to business success. The reason is that it helps organisations to improve their internal and external processes, as well as the customer experience, among other things (Emprendedor Growth Model, 2022).

It should be noted that innovation encompasses new approaches, procedures and concepts, enabling the implementation of new tactics or even completely new organisational designs with the aim of revitalising organisations, winning more customers, fostering organisational change and accelerating expansion. (Porter, 1998)

Therefore, innovation is one of the most important aspects in terms of transformation, growth and process optimisation. However, if we talk about more specific benefits, the following are worth highlighting:

- Innovation increases profit margins.
- It allows companies to differentiate themselves from the competition with their goods or services.
- It helps to reduce weaknesses to improve customer satisfaction and thus increase customer loyalty.
- It strengthens the company's strategic position in the market.
- It favours the exploitation of new business opportunities.
- It enables companies to expand and penetrate new markets.
- It encourages creative thinking and teamwork among all members of the organisation.
- Improvements in internal communication.
- Strengthens brand and business reputation.

However, for innovation to be as effective as possible and for its benefits to be realised, it needs to be underpinned by two fundamental factors:

- The context, values and mission of the company are appropriate to foster innovation.
- Good communication that allows important ideas about innovation to reach all members of the organisation and create value.

If innovation is built on these pillars, it not only guarantees success and the best use of its benefits, but also creates added value for the company (Emprededor Growth Model, 2022).

2.2.7. GREEN INNOVATION

Within the topic of innovation, we find green innovation, which is related to the development of products or initiatives oriented towards sustainable and environmentally friendly solutions.

This type of innovation has gained momentum in recent years, especially due to the needs of organisations and countries to meet the sustainable development goals agreed by the UN in 2015 (United Nations, 2021). For this reason, countries must define indicators in order to standardise and monitor their efforts in this area in order to achieve the established goals.

We go on to define the term *green innovation* through the definitions of different authors, in order to better understand this concept.

According to Tietzer & Herstatt (2011), the concept of green innovation encompasses four innovation-related terms that aim to reduce environmental impact, considering the life cycle approach in the analysis. These terms are: green innovation, environmental innovation, sustainable innovation and eco-innovation.

Focusing on the concept of eco-innovation, it is defined as the creation of any new or improved product, process, organisational change or marketing strategy that saves resources and reduces the release of harmful substances throughout the product life cycle (Innovation Observatory, 2011).

On the other hand, (Porter & Vander Linde,1995) make a distinction between conventional innovations, which are not developed to address environmental challenges, and green innovations, which are developed to meet the requirements of regulatory agencies or customer concerns.

In this context, (Driessen & Hillebrand,2002) explain that green innovations do not necessarily have to be created with the specific intention of reducing the environmental burden, but their introduction should generate significant environmental benefits.

Whereas, (Chen & Lai,2006) define green innovation as innovation in technological breakthroughs related to energy conservation, pollution prevention or corporate environmental management. Furthermore, according to Rennings (2000), green innovation emphasises sustainable development.

Finally, according to Oltra (2009), the term "environmental innovation" refers to a set of innovations that involve new or improved procedures and practices that benefit the environment and therefore support environmental sustainability.

Having defined the term green innovation, we will focus on the term green or clean technology, which is a term frequently used to refer to innovations that are beneficial to the environment. More specifically, the term refers to innovations or products that support sustainability, reduce greenhouse gas emissions or reduce the effects of climate change (Chu, 2013).

Having defined and analysed the term green innovation from different perspectives, we can draw the conclusion that there is no single term that defines green innovation. However, we can observe that all definitions have a common denominator, the quality of being environmentally beneficial.

2.3. RELATIONS BETWEEN CLUSTERS AND INNOVATION

According to Porter (1990) territorial agglomeration of firms has traditionally been conceptualised, among others, as the industrial cluster concept.

Previous research has shown that firms are driven to move closer to each other in order to obtain shared external resources. Due to geographical location, firms and organisations benefit from the exchange of external information and knowledge through location.

Therefore, we can define a cluster as an ideal setting for the development, application and expansion of the innovation process. Because of this, research links clusters and geographical location with the innovation capacity of an organisation.

Furthermore, in his book *On Competition*, Porter (1998) identifies the factors that promote innovation within a cluster. Among these factors, the presence of informed buyers stands out, who are a valuable source of information on emerging technologies and markets. In addition, the existence of specialised suppliers allows firms to have high levels of flexibility and speed in introducing innovations. Mutual support between firms and competitive rivalry also play an important role in fostering research and development in the cluster.

In their research, (Khan & Ghani,2004) argue that new technologies diffuse rapidly due to factors such as proximity, trust, competition and subcontracting arrangements.

Equally important, there are other factors that contribute to the presence of innovation in a cluster, such as existing interconnections that allow the perception of new opportunities and ways of competing related to specialisation, subcontracting networks, horizontal and vertical networks, as well as the formation of strategic alliances between firms and other actors.

In particular, specialisation leads to a division of labour among firms, which tests competitiveness within the cluster and encourages the implementation of specific innovations.

In conclusion, innovation and clusters are closely linked. They allow to promote the development of technical and commercial competences, to obtain a higher concentration of talent, to attract potential investors and to increase the connection between the companies that form the cluster with other related companies that can offer useful resources and ideas for the development of innovation.

3. METHODOLOGY

During this work, we have used several secondary sources to obtain different types of information. These sources have allowed us to analyse in detail the Spanish ceramics sector, to make data comparisons and to understand the functioning of the ceramic industry, focusing on the ceramic cluster located in the province of Castellón. Next, we are going to present the methodology we have followed while carrying out the work:

1. Use of sectoral reports by associations related to the Spanish ceramics sector, such as ASCER, ANNFEC or ALICER, which through various reports have provided us with an overview of the Spanish ceramics sector, including aspects such as production, exports, innovation, digitalisation, sustainability, among others. These reports have provided us with both quantitative and qualitative information, allowing us at all times to know the current state and trends of the sector.
2. On the other hand, we have used publications on the Spanish ceramics sector, which have provided us with valuable information on advances and research in the field of ceramics, as well as on the main trends and problems in the sector.

Among the publications we have used, the company Macer has provided the book "Presses, moulds and pressings in the manufacture of ceramic tiles", which was written by Rafael Galindo Renau. This book has allowed us to understand how pressing works in the production process.

In addition, we have also used theses and academic works on the ceramic sector that have allowed us to acquire information on the ceramic cluster.

3. We have also used statistical data from various public sources, such as the Instituto de Tecnología Cerámica (ITC) or the study on the degree of implementation of environmental strategies in the ceramics sector prepared by Desmarca for the Chair of Transformation of the Economic Model Jaume I University - GVA, providing us with statistical data on production, exports, imports, sales, employment and other relevant aspects of the Spanish ceramics sector. These data have allowed us to know the evolution of the sector in figures and to compare it with other sectors or countries.

4. Finally, we have analysed information from articles by organisations and companies in the sector and related to it, which have provided us with relevant information on their operation, their range of products and services, their innovation and digitalisation strategies, their sustainability practices and other aspects of interest.

In summary, the sources of information on the Spanish ceramics sector have provided us with specific information that complements the general vision of the sector and allows us to go deeper into specific aspects.

4. SPANISH CERAMIC CLUSTER

After introducing the concept of cluster within the theoretical framework, we proceed to describe the current situation of the Spanish ceramic cluster. In this section, we will analyse the origin of the cluster, as well as the characteristics and typology of the companies that make it up. Subsequently, we will focus on the concept of the ceramics industry, examining the production process and the benefits that this industry brings to the Spanish economy.

4.1. ORIGIN OF THE CERAMIC CLUSTER

According to (Hervás Oliver, et.al,2014) the entry of the ceramic industry in Spain took place during the period of the Islamisation of the Iberian Peninsula. During this period, Andalusia became one of the main centres for the manufacture and marketing of ceramic products. Ceramic products began to be used and demanded at the beginning of the 13th century, which led to a significant growth in the ceramic industry, giving it greater development and prominence in the region.

As the years went by and the need and pressure exerted by the Christians to move the ceramic industry to the region of Valencia, as it was a strategic place for its distribution and commercialisation, caused the industry to move to Manises. This move had a positive influence on the export of ceramic materials to countries such as Egypt and Turkey, but most of the Spanish ceramic exports were sent to Italy.

This export to Italy meant that, in the 16th century, Italian ceramists introduced new innovations on the ceramic product, creating new shapes and adding decoration to the ceramic materials, with different colours. This caused a fall in sales and Spanish exports, specifically a fall of the ceramic companies located in the area of Manises, because the products produced by the Spanish ceramic industry were monochromatic and did not sell as well as those made by the Italian ceramists. (Alfonso,2015).

The fall of the ceramic industry in Manises caused the transfer and relocation of the industrial centre to the capital of the region of Valencia, where the design and manufacture of innovative ceramic pieces began, which were used in different cultural periods, such as the Baroque and Valencian classicism. (Hervás Oliver, et.al,2014).

Focusing on the Spanish ceramic cluster currently located in the province of Castellón. Its beginnings date back to the 18th century with the foundation of the Royal Factory of

the Count of Aranda in Alcora, which was set up in this geographical area due to the easy access to the materials necessary for production, in particular the key access to the high quality red clay quarries and the proximity to the maritime areas that allowed the products to be exported. In addition, at this stage we can observe the first agglomerations of companies based on the tradition of the Arab kilns spread throughout the area, which allowed the creation of links between companies and complex family business groups.

The foundation of the Real Fábrica de Cerámica (Royal Ceramics Factory) led to new materials being used in the villages around Alcora and the creation of a ceramics school in Onda, which led to the creation of new products and the introduction of tiles (Hervás Oliver, et.al,2014).

At the end of the 19th century, the Spanish ceramics industry settled in the industrial production centres of the province of Castellón, bringing together a large number of companies dedicated to the production of ceramic products.

From the twentieth century onwards, new technical developments took place, both in the machinery used for production and in the preparation of raw materials. Although everything pointed to a rapid expansion of production, this was frustrated by the financial crisis of 1929, the Spanish Civil War and the Second World War. (Alfonso,2015).

The first industrial reconversion in the ceramics sector took place in the 1970s. This produced a radical innovation in the production system, allowing the complete automation of the production process and saving energy and time. This reconversion consisted of a change from a double firing production system to a single firing system.

On the other hand, in the 1980s a production change was made to reduce the pollution of their processes and switch from fuel to gas as a source of energy, which, together with external connections with the Sassuolo cluster, allowed the incorporation of new machinery and equipment.

In the 1990s, thanks to these introductions, they were able to overtake China as the leading ceramics producer. However, there is increasing competition on a global scale and, in addition to Italy, new tile-producing nations such as Brazil, China or Mexico are competing with Spain in terms of production.

The competitive increase led Spanish ceramic production to introduce efforts to raise the quality standards of its production, boosting the added value per unit of production with the aim of reaching the quality standards of its rivals.

The concentration of companies helped to share knowledge acquired by each of them to make production processes more efficient and create a better product for the customer. This concentration formed the ceramic industrial cluster of the province of Castellón, which had over the years an exponential growth due to the proximity of the companies and the proximity of the resources to create the ceramic product.

All this, together with the introduction of new techniques, combustion gases and new materials, influenced the growth of the Spanish ceramic industry, which is currently ranked second in the world ranking of exporting ceramic companies and fifth in world production.

In conclusion, the Spanish ceramic cluster was formed as a result of a long history of ceramic production in the region. Since this time, the ceramic industry has been growing and evolving, which allowed manufacturers to produce higher quality products at lower prices, attracting a large number of investors (such as new companies dedicated to a part of the ceramic tile value chain, allowing for better synergy), auxiliary companies (such as the Instituto Tecnológico de la Cerámica (ITC) or associations such as ASCER, which try to promote innovative and sustainable projects, helping at all times the growth of the Spanish ceramic industry) and public bodies (managing the quality processes and offering certifications to companies that meet the requirements set by the legislation), which contributed to the development of the cluster.

In addition, Spain's geographical location has become a key factor for the existence and success of the ceramic cluster, as its location close to the main European markets allows them to have access to the materials necessary for ceramic production, as well as better connectivity with other countries.

As it is a very dynamic industry that promotes the introduction of new technological advances, both in production processes and in the acquisition of new products, the Spanish ceramic cluster has become a role model for the rest of Europe. The sector's achievements have boosted the local economy by generating jobs and fostering growth.

4.2. CHARACTERISTICS

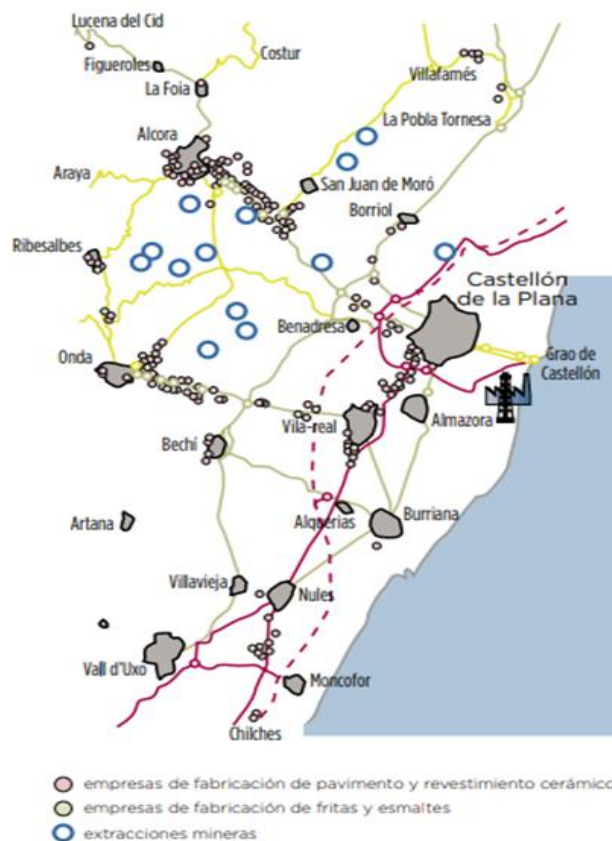
In the province of Castellón is located an important production center of ceramic wall and floor tiles, both in Spain and worldwide (Del Corte Lora,2015).

Being the first producer in the European Union, Spain produces 10% of the total amount of these goods produced worldwide, representing 40% of the market.

One of the main characteristics of the Spanish ceramic industry is the high concentration of companies, forming the ceramic cluster in the province of Castellón with an area of about 30 km², located in the border area of Alcora and Borriol to the north, to the west with Onda and Ribesalbes, to the east with Castellón de la Plana, to the south with Nules. In addition to this central nucleus, there was also ceramic activity in the interior.

The region presents the characteristics of a mature local productive system, which has developed innovative productive processes that have favored a remarkable economic growth and socio-institutional development (Salom & Albertos, 2006).

Figure 3:Map of the Spanish Ceramic Cluster

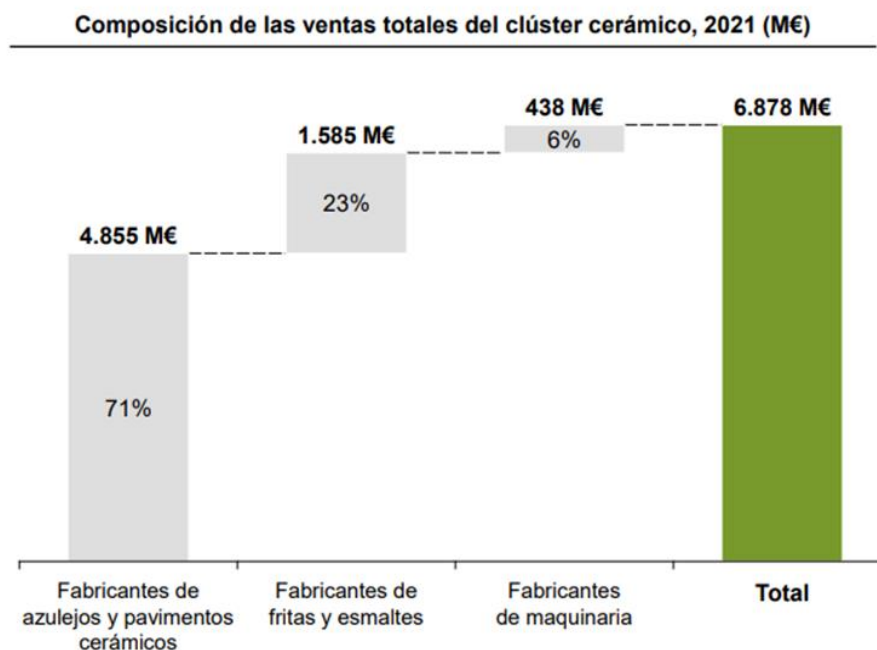


Source: Universidad Miguel Hernández y Universidad Jaume I ,2008

Focusing on the production of ceramic floor and wall tiles in Spain, we can see that 80% of the companies in this sector are located in the province of Castellón, where 94% of production takes place. According to the classification made by *elEconomista.es* in its report that establishes the ranking of companies using the CNAE code 2331 in the province of Castellón, the cluster is currently made up of 106 companies dedicated to the production of ceramic tiles.

Manufacturing companies that produce frits and glazes, ceramic tiles and floor tiles, as well as machinery, make up the ceramic cluster in the province of Castellón, which had a turnover of 6,878 million euros in 2021, 25.6% more than in 2019.

Figure 4: Total turnover cluster

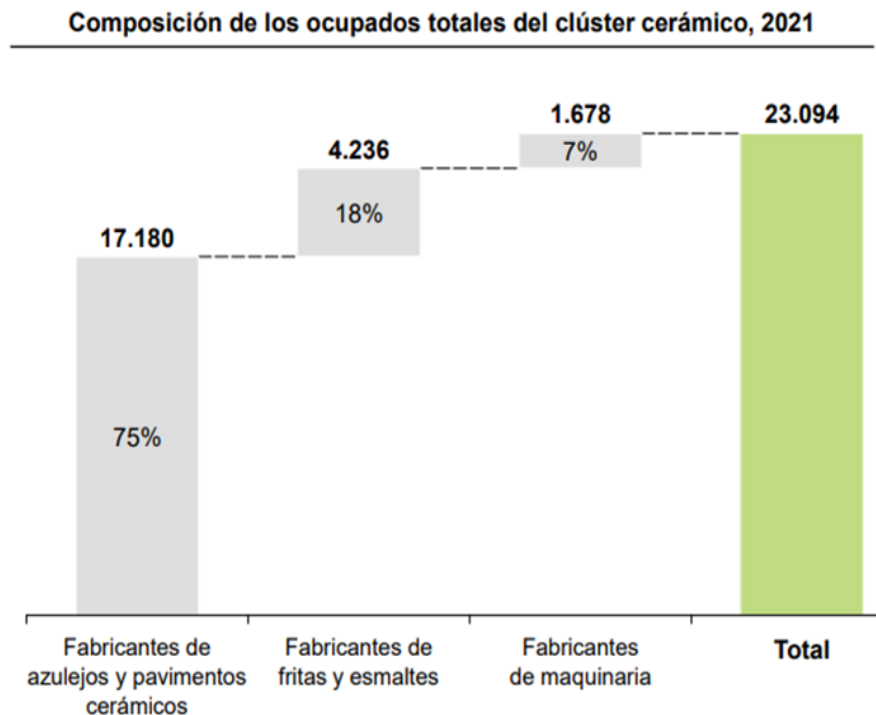


Source: *Ascer, 2021*

The productive activity of the ceramic cluster with the greatest weight, with 71% of the total turnover, is the production of ceramic tiles and floor tiles. The producers of frits and glazes occupied the second place with 23% of the market share, their main market being the domestic market, as they sell their production to companies dedicated to the production of tiles, and finally the producers of equipment occupied the third place with 6%, this allows us to confirm that the companies that make up the ceramic cluster are highly globalised and are prone to export their production.

On the other hand, the ceramic cluster has generated employment for 23,094 people, achieving an increase of 9.2% compared to 2019. With 75% of the total number of employees in the cluster, the ceramic tile and flooring industry is the activity with the highest number of employees. It is followed by frits and glazes producers with 18% of the workforce.

Figure 5: Total employment generated by the cluster.

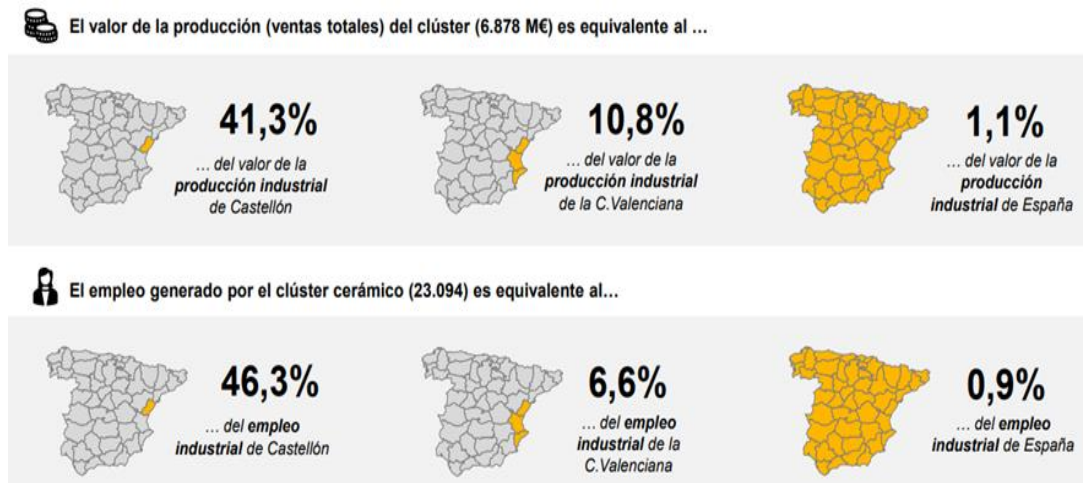


Source: ASCER, 2021

The ceramic cluster industries employ a large number of people, many of whom have higher education and specialised technical training. In addition, the cluster offers high quality jobs because more than 95% of the cluster's employees have long-term contracts, which gives the industry more stability during economic downturns.

Moreover, workers can specialise and be more productive in the cluster due to its high specialisation and productivity. It also provides incentives for the introduction of new processes that have reduced atmospheric emissions of pollutant gases by more than 50% since 1985.

Figure 6: Cluster contribution to production and employment



Source: ASCER, 2021

In conclusion, the cluster contributes directly to tax revenue (through taxes paid) and indirectly (by generating economic activity in Spain).

4.3. CLUSTER COMPOSITION AND COMPANY TYPOLOGY

A cluster is defined as a grouping of interrelated and geographically concentrated companies and institutions competing in the same sector or business (Porter, 1990).

Taking the Spanish ceramics cluster as an example, we can see that it is made up of various companies located in different links of the value chain, including both producers of goods and suppliers of complementary services, institutions and related organisations, such as universities, research centres and government bodies.

This collaboration between cluster stakeholders contributes to the exchange of knowledge, the promotion of innovation and the boosting of the growth and competitiveness of the ceramic sector in Spain.

Business-to-Business Networks

Depending on the type of company operating in the cluster, we can observe two different business approaches. The first approach we can observe is the integration of different stages of the production process within the same company. On the other hand, the other refers to the specialisation of certain stages of the production process, especially those activities that provide greater added value or require greater specialisation or technology. Thus, we can find the following types of companies in the Spanish ceramic cluster:

- The companies dedicated to the production of ceramic floor and wall tiles integrate all the stages of the production process, from the atomisation of the clay to the manufacture of the product. These companies represent the most important group of producers in the ceramic cluster in terms of size, turnover and workforce.
- Fogging companies are responsible for converting the clay into a material that is then used for the production of ceramic tiles. In some cases, paving companies have established relationships with companies that specialise in spraying to secure the supply of raw materials. Increased imports of raw materials, mainly from Ukraine, Turkey and the UK, are essential for the development of new products such as porcelain and whitewashed ceramics.
- Companies producing frits or glazes. They work closely with manufacturers to develop new products and production methods. The type of glaze is crucial to both the quality of the product and its ability to decorate and design.
- Special parts companies refer to companies that provide products according to the design needs of manufacturing companies and on behalf of manufacturing companies. They are usually small in size and place a greater emphasis on technological and product innovation.
- On the other hand, we can observe the companies that are in charge of activities that are not so closely linked to production, such as the companies that extract and transport raw materials, as well as the companies that transport the final product.
- Finally, we find companies dedicated to the production, repair and service of machinery related to the ceramics industry.

After analysing the different companies involved in the production process, we can be sure that the production chain of the ceramic cluster generates a dense network of cooperative relationships that enables the dissemination of information and innovation, which homogenises the characteristics of the ceramic cluster to a great extent.

However, these are not the only agents present in the cluster, as the productive system is characterised by a high density of institutions and organisations, developed in response to the needs of the sector.

Institutional Bodies

Therefore, we identified different organisms according to the classification system established by (Méndez,2000):

1. Business associations

Among the various business associations related to the Spanish ceramic cluster, the Asociación Española de Fabricantes de Azulejos y Pavimentos (ASCER) stands out as one of the most important. This association represents the Spanish ceramics industry at national and international level, and plays a key role in promoting the interests of the sector and collaboration between ceramic companies.

There are also other organisations linked to the ceramic frits and glazes business sector, such as the National Association of Ceramic Frits and Glazes Manufacturers. These organisations aim to promote the development and competitiveness of companies dedicated to the production of frits and glazes, providing technical support, representation and promotion of their interests.

It should be noted that, due to the high concentration of ceramic companies in the province of Castellón, all these associations are based in this province, although their scope of action covers a national level, representing companies from all over the country involved in the ceramic sector.

2. Professional associations

As far as professional organisations are concerned, we can highlight the role of the Asociación de Técnicos Cerámicos (ATC) and the Official College of Engineers, which have played a significant role in the dissemination of knowledge and technology in the industry.

3. Trade unions

We can highlight the presence of trade union groups such as the UGT and the CCOO, which work to defend and promote the rights of the members of the ceramics cluster in terms of wages, benefits and working conditions.

4. *Technology centres*

The technology centres linked to the cluster help to promote projects and boost technology within the sector. We can highlight the following.

- Integrated within the Jaume I University of Castellón is the Instituto de Tecnología Cerámica (ITC). The ITC's functions include research and development, dissemination of commercial and technological information, quality control and certification and other technical support services.
- The dissemination of knowledge on technological advances and design, training and trend research are the main activities of the Asociación para la Promoción del Diseño Industrial Cerámico (ALICER).
- On the other hand, we find the Institute for the Promotion of Ceramics, which acts mainly as a documentation centre under the control of the Provincial Council of Castellón.
- Finally, we can observe some additional institutions external to the cluster. Such as the Centro para el Desarrollo Tecnológico Industrial (CDTI), an organisation mainly dedicated to the promotion and funding of research projects. This organisation maintains exclusively funding and support connections with the largest and fastest growing companies.

5. *Training Centres*

We can differentiate between different training centres:

- Universities: The Jaume I University of Castellón and the Polytechnic University of Valencia are the most closely linked to innovation projects.
- Vocational Training Centres, where we highlight the Escuela Superior de Cerámica de Alcora, which offers the qualification of higher ceramics technician.

6. *Administration*

State, regional and local governments interfere in the ceramic cluster in different ways.

7. *Trade fairs*

It is important to highlight the ceramics fairs, specifically CEVISAMA, which is held annually in Valencia to promote technological and productive advances related to the ceramics industry. This fair attracts thousands of visitors and various companies related to the sector, and is the most significant event due to its strategic importance for the Castellón ceramic cluster.

4.4. SPANISH CERAMIC INDUSTRY

Due to its role in the production of wealth, job creation and the maintenance of a positive trade balance, the ceramics industry is an important and strategic player in the industrial fabric of Spain and the Valencian Community, especially in Castellón. This importance extends beyond the manufacturing process as its exporting character, research, innovation and sustainability, among other factors, have a stimulating effect on the whole ceramic group.

As a result, the ceramics industry is one of the most dynamic and forward-looking industries in Spain.

Focusing on the main activity of the ceramic industry, the production of ceramic tiles and floor tiles, we can see that it occupies a prominent place internationally in terms of exports and production of ceramics, competing with countries such as China, which accounts for almost half of the world's production, Brazil, India and Italy, which in recent years is increasing its production again, after seeing its production interrupted in 2020 due to the economic, health and social crisis of the Covid-19.

Figure 7: Top producing countries

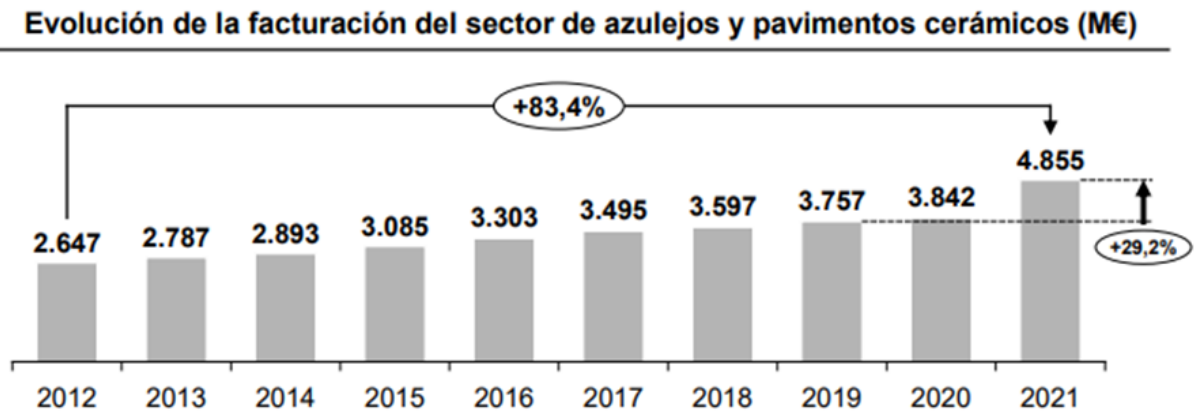
TOP MANUFACTURING COUNTRIES							
COUNTRY	2017 (Sq.m Mill.)	2018 (Sq.m Mill.)	2019 (Sq.m Mill.)	2020 (Sq.m Mill.)	2021 (Sq.m Mill.)	% on 2021 world production	% var. 21/20
1. CHINA	10,146	9,011	8,225	8,474	8,863	48.3%	4.6%
2. INDIA	1,897	2,011	2,223	2,318	2,550	13.9%	10.0%
3. BRAZIL	867	872	909	840	1,049	5.7%	24.9%
4. SPAIN	530	530	510	488	587	3.2%	20.3%
5. IRAN	373	383	398	449	458	2.5%	2.0%
6. TURKEY	355	335	296	370	438	2.4%	18.4%
7. ITALY	422	416	401	344	435	2.4%	26.5%
8. INDONESIA	307	383	347	304	410	2.2%	34.9%
9. VIETNAM	560	602	560	534	370	2.0%	-30.7%
10. EGYPT	300	300	300	285	310	1.7%	8.8%
TOTAL	15,757	14,843	14,169	14,406	15,470	84.4%	7.4%
TOTAL WORLD	18,208	17,430	16,803	17,101	18,339	100.0%	7.2%

Source: Acimac Research dept. "World production and consumption of ceramic tiles", 10th edition

As we can see in the table, Spain is the first European producer country, rising to the fourth position in the world ranking, since in the year 2021 it managed to produce 587 million m², 20.3% more than in the previous year, which means an increase in production that can be seen as an increase in the production capacity of the Spanish ceramic industry, but we must also take into account that the previous year we suffered a health crisis, which reduced the production numbers and income of the vast majority of Spanish industries.

As far as exports are concerned, the Spanish industry is in second place in the ranking (since 75% of the final product is exported, leaving only 25% of production to satisfy domestic consumption of ceramic tiles) behind China. Although we are in second place in the export ranking, this does not mean that we obtain a higher profit than others below us. In the Spanish industry, the average price of the products marketed is around 7€/m² (ASCER, 2021). On the other hand, in the Italian ceramic industry it is 14€/m², thus allowing us to obtain higher sales value (Vigilancer,2021).

Figure 8: Evolution of sales in the Spanish ceramics industry



Source: ASCER, 2021

The exporting nature of the Spanish ceramics industry has led to an 83.4% increase in sales since 2012. This evolution demonstrates the high growth capacity of the sector and its importance in the growth of the provincial and regional economy. In 2021, total turnover increased by 29.2% compared to 2019 and by a higher percentage than production, showing an increase in the value of the ceramic product.

Figure 9: World ranking of ceramics companies

	Group / Company	Production (mill. sq.m)	Installed capacity	Export share	Turnover only tile segment (mill. €) ¹	Total turnover (mill. €)	Tile plants / Location	Main Tile Brands / Companies
1	MOHAWK INDUSTRIES, INC. USA	250.0 (estimates)	250.0 (estimates)	n.a.	\$ 3,920 mill.	\$ 11,201 mill. (ceramics, carpet, laminate, wood, stone, LVT)	23 in USA, Mexico, Brazil, Italy, Spain, Poland, Bulgaria, Russia	American Olean, Dal Tile, KAI, Kerama Marazzi, Marazzi, Ragno, Emilgroup, Eliane
2	GRUPO LAMOSA MEXICO	197.1	213.5	47%	632.4	1,166.2 (tiles, adhesives)	9 in Mexico, 2 in Argentina, 2 in Colombia, 3 in Peru, 3 in Brazil, 1 in Spain	Lamosa, Porcelanite, Firenze, San Lorenzo, Cordillera, Scop, Princesa, Mallorca, Lamosa USA, Euroceramica, Gala, Roca, Incepa
3	SCG CERAMICS THAILAND	139.0	187.0	14%	536.0	663.0 (tiles + sanitaryware)	17 in Thailand, 7 in Vietnam, 1 in Indonesia, 1 in Philippines	COTTO, Sosuco, Campana, Prime, Mariwasa, Kia, Trend, Impresso
4	GRUPO PAMESA SPAIN	101.0	101.0	68%	881.7	1,220.6 (tiles, raw materials, energy)	8 in Spain	Pamesa, TAU, Geotiles, Prissmacer, Ecoceramic, Navarti
5	RAK CERAMICS UAE	99.0	118.0	60%	467.0	685.0 (tiles, sanitary, tableware)	12 in UAE, 1 in Bangladesh, 1 in India	RAK Ceramics, Elegance
6	CERAMICA CARMELO FIOR BRAZIL	97.2	98.4	23%	n.a.	n.a.	5 in Brazil	Cecafi, Pisoforte, Fioranno, Ideale, Arielle
7	KAJARIA CERAMICS ² INDIA	91.0 (sales)	82.8	2%	417.0	451.0 (tiles, sanitaryware)	10 in India	Kajaria
8	STN GROUP SPAIN	89.8	92.0	76%	453.2	453.2	3 in Spain	STN, Alaplana, Keratile, Tesany, Vitacer, KTL
9	ARWANA CITRAMULIA INDONESIA	69.1	71.7	1%	158.4	158.4	5 in Indonesia	Arwana, ARNA
10	GRUPO CEDASA BRAZIL	67.7	70.0	5%	n.a.	n.a.	1 in Brazil	Cedasa, Majopar, Vistabella, Lorenza
11	GRUPO FRAGNANI BRAZIL	65.4	79.0	9%	189.4	189.4	3 in Brazil	Incefra, Incenor, Tecnogres, In Out, HD-Max
12	CERSANIT SA POLAND	63.1	66.7	67%	287.1	524.0 (tiles, sanitaryware)	2 in Poland, 2 in Russia, 1 in Ukraine	Cersanit, Opoczno
13	SAUDI CERAMICS SAUDI ARABIA	60.0	70.0	10%	240.0	400.0 (tiles, sanitaryware)	6 in Saudi Arabia	Saudi Ceramics

Source: Vigilancer, 2021

As far as national ceramic companies are concerned, with a production of more than 100 million m², Pamesa is the leading national manufacturer, occupying fourth place in the world ranking of ceramic manufacturers. As a result, it continues to be the leading ceramics producer in Europe.

For its part, STN produced 90 million m² in 2021, occupying eighth place and dropping one position in the world ranking compared to last year. Despite losing one place in the ranking, it still managed to significantly increase production compared to 2020.

Likewise, in 2021, the British corporation Victoria PLC, owner of ceramic businesses based in Castellón such as Keraben or Saloni among others, dropped one place in the table and was placed in seventeenth position.

Finally, it is worth mentioning that with a production of 41 million m² in 2021, Grupo Halcón closes the top 25 of producing companies worldwide.

In conclusion, after analysing the Spanish ceramics industry and the companies with the greatest production capacity, we can conclude that it is one of the most outstanding ceramics industries worldwide. For this reason, the Spanish ceramics industry is characterised by its dynamism and the solid cooperation between the companies that make it up, which allows it to effectively face the rivalries of the environment and obtain a favourable competitive position in relation to its competitors.

4.4.1. PRODUCTIVE PROCESS

The Spanish ceramics sector is made up of various companies involved in different production processes, which are integrated to obtain the final product. In the Spanish ceramics cluster, the geographical proximity between companies fosters greater cohesion between them.

This cohesion allows the coexistence of companies specialising in different areas, such as the production of ceramic tiles, the atomisation of clays and the manufacture of bisque, the production of frits, glazes and ceramic colours, the manufacture of machinery and the extraction of raw materials in mines. These activities contribute to the specialisation of processes in ceramic companies and also generate employment in the sector.

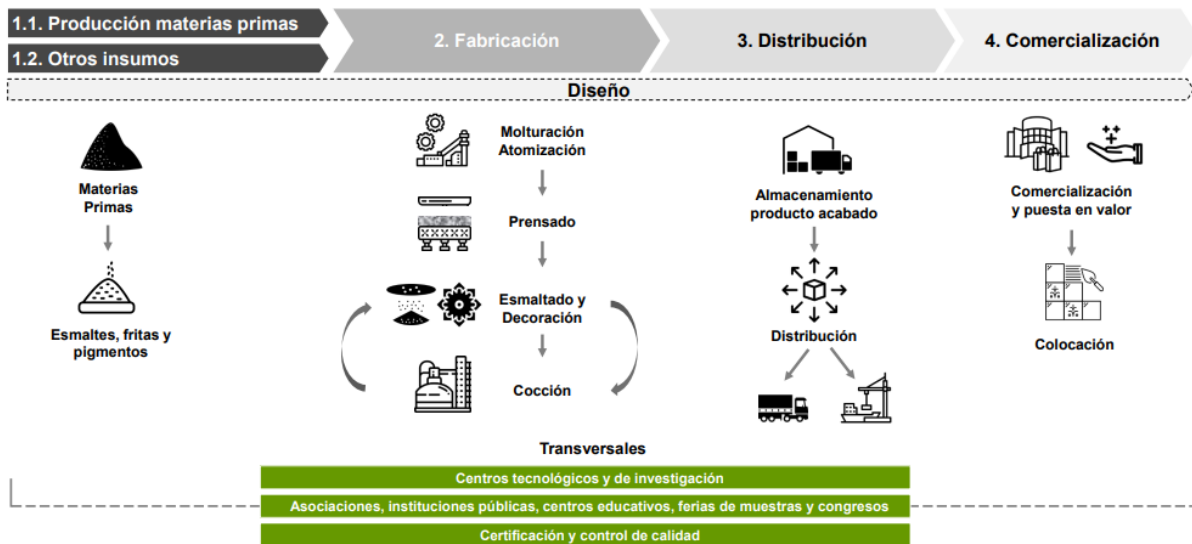
In this context, we focus on the main activity of the ceramic industry, which is the production of ceramic tiles. This group of companies is the most important within the sector, both in terms of turnover and number of employees.

The CTL (Centro de Tecnología Limpia) describes ceramic tiles as thin slabs of clay or other inorganic material that are often used to cover floors and walls. To achieve the desired properties, ceramic tiles generally undergo extrusion or dry pressing processes at room temperature, followed by drying and firing at elevated temperatures to ensure that they acquire the properties required for their use.

At present, the ceramics industry has around 140 companies dedicated to the manufacture of ceramic tiles, according to the data provided by the ranking of companies established by elEconomista.es.

Focusing on the production of ceramic tiles, we are going to analyse the production processes carried out to obtain the final product, from the extraction of raw materials to their distribution.

Figure 10: Ceramic production process



Source: ASCER, 2021

The ceramic production process is a highly automated in-line process consisting of the following basic operations: 1) selection, procurement and preparation of raw materials and other inputs, 2) design, 3) manufacture, 4) storage and distribution, 5) marketing.

1. The selection and preparation of raw materials is the main phase for the subsequent production of ceramic tiles. In this phase, the different raw materials are extracted from mines or quarries, such as clays, kaolins, sands and many other materials, which after extraction are transported to their destination by lorries or trains. It should be noted that 75% of the raw materials used are imported.

Depending on the product to be produced, different ingredients will be used, which will be mixed and milled to achieve homogenisation and an optimum size that will allow the material to be suitably plasticised for its subsequent shaping.

As far as frits, glazes and pigments are concerned, they are of great importance in the first stage of the ceramic tile production process, as they provide the colour and finish of each product and have a strong impact on the final product. In this process there is a high level of specialisation of the employees, due to the fact that a large percentage of the employees in the ceramic industry specialising in frits, glazes and pigments have university degrees.

In this process, it is worth highlighting the role played by the Asociación Nacional de Fabricantes de Fritas, Esmaltes y Colores Cerámicos (ANFFECC), fostering innovation,

promoting research and development, thus improving the interrelation with the rest of the phases of the ceramic process.

2. The second phase of the production process is of great importance in the value chain, due to the fact that the design of the product conditions the selection of raw materials for its subsequent manufacture, as the materials to be used in the product to be manufactured are chosen from the design, which adds value to the final product.

At present, there are companies that have their own design department. But there are others that outsource these processes due to the proximity of the companies that make up the ceramics cluster. The companies dedicated to the production of frits and glazes are the ones that are usually in charge of creating designs that other companies want to implement. In addition, the proximity between the companies in the ceramic cluster helps to create synergies, producing products with different finishes and shapes.

3. The production phase begins with the preparation of the raw material; the most common process is the wet process, in which the raw material is crushed with water and then atomisation dried.

After drying the raw material, we obtain an atomised powder consisting of hollow homogeneous spherical particles, which are advantageous for filling and pressing moulds. Once the raw material has been ground and atomised, the product we obtain from the process must have optimum humidity conditions so that the subsequent drying, firing and glazing process is correct and we can obtain the final product with the appropriate quality standards.

Pressing is a moulding operation based on the compaction of powders in rigid, homogeneous and flexible moulds by means of pressure. Depending on the type of pressure applied, there are different types of isostatic pressure pressing (including pressure applied perpendicularly to the formed surface, which is usually used for complex geometries or very large sizes) and one-sided pressing (including head pressing powder into the mould by applying pressure from above and from below, i.e. bidirectionally, whereas if it is applied only on one side, it will be a unidirectional axial pressure).

Therefore, the dry pressing system is widely used in the production of ceramic tiles due to its efficiency and automation. The main objective of this process is to obtain a high quality product with precise dimensions and a suitable microstructure to meet the specific

requirements of each manufacturing stage and to achieve the desired characteristics in the final product.

Once the pressing process is completed, the product is glazed and decorated. During this stage, layers of glaze are applied to the ceramic material using different methods to cover the entire surface of the object. This is done in order to give the product technical and aesthetic properties, such as impermeability, gloss, colour and texture, among others.

In recent years, embellishments have been applied digitally, allowing the final products to have a different finish, helping companies to improve the impression of their work and reduce costs.

Finally, we have the firing process, which is the most important and interesting step in the manufacturing process, as it is carried out at temperatures above 900°C, where its physicochemical properties are transformed. Transforming the pieces obtained during the previous processes into a solid and durable material with technical properties that define the ceramic product.

In some cases, after firing, the material is processed, smoothed or polished to achieve better results in the final product.

4. The fourth stage of the ceramic tile production process consists of packing and transferring the final product to the warehouses for its subsequent marketing.

Ceramic tiles are very resistant materials, which facilitates their transport and handling.

Once stored, they are ready for subsequent distribution. In the Spanish ceramic industry, 75% of production is exported to other countries, hence the importance of ceramic activities in the Valencian Community, exporting more than 50% of total ceramic production from its ports.

5. The last stage of the ceramic tile production process is the marketing and installation of ceramic tiles.

Firstly, as far as marketing is concerned, ceramic companies promote their products through fairs, events, institutions and associations (such as ASCER using the Tile of Spain brand to represent the ceramic product), thus making their products known.

Once marketed, the last step is the installation of the product. This process is essential as the ceramic tile becomes the final product, which is why optimum installation quality must be guaranteed.

Apart from the stages carried out to achieve the final product, there are different activities, organisations and companies indirectly dedicated to the growth of the sector.

Such as technological research centres and universities that are responsible for innovating and promoting projects along the value chain, in order to create new production processes that help to produce in a sustainable way and improve product quality. It is worth mentioning the Instituto Tecnológico de la Cerámica (ITC), which helps ceramic companies through projects to invest and generate innovation, which can influence in the future to improve the positioning of ceramic companies.

On the other hand, we can see associations, fairs and public institutions which help to make ceramic products and processes known. Defending the interests of the ceramic industry and promoting the Spanish product all over the world. One of the most important fairs of the Spanish ceramics sector is CEVISAMA, a fair that takes place in Valencia and brings more than 90.000 visitors interested in ceramic materials.

Another activity that ceramic industries carry out indirectly from their production is the process of quality and safety control which they have integrated in order to obtain certificates and to improve the way of working of the employees and the quality of their products.

4.4.2. BENEFITS FOR THE SPANISH ECONOMY

The Spanish ceramic tile industry, backed by the Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos (ASCER), has an outstanding position worldwide. With a production that represents 10% of the world total, it is positioned as the main producer in the European Union, with a market share of 40%. These figures demonstrate the importance and leadership of the Spanish ceramics industry on the international scene.

This outstanding position entails numerous benefits for the sector and for the economy in general. Firstly, the Spanish ceramics industry generates a large number of direct and indirect jobs, which contributes significantly to the creation of employment opportunities in the country. Moreover, its leading position in the European Union implies a

considerable export of ceramic products, which strengthens the trade balance and generates income for the national economy.

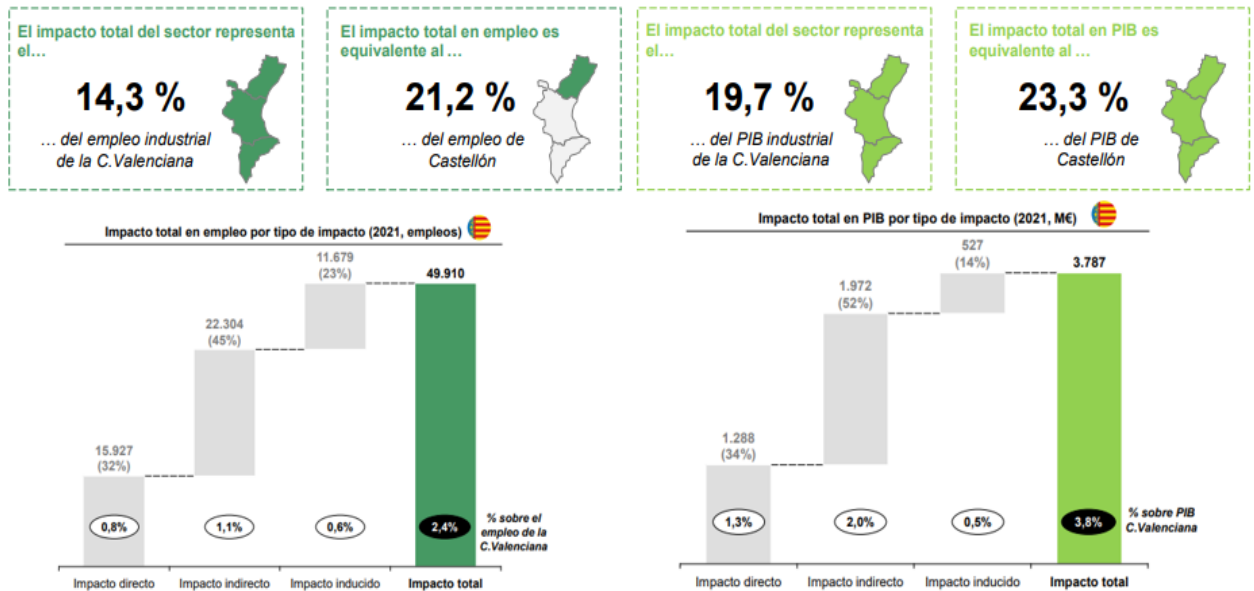
Furthermore, the Spanish ceramics industry is characterised by its constant innovation and search for improvements. This translates into the introduction of new technologies, designs and materials in its products, which increases their quality and diversity. As a result, the Spanish ceramics industry remains competitive in the global market and contributes to the economic development of the country.

As regards employment in the Spanish ceramics industry, it has maintained a steady growth of 1.3% per year since 2012. For this reason, direct employment has increased by 10% since 2012. This growth in staff in the Spanish ceramics industry is lower than the total turnover of the sector, which allows us to observe that the productivity of employees has increased over time.

On the other hand, due to the continuous technological and production process innovation that is taking place in the sector, it allows employees to specialise and bring significant value to the production process. Consequently, since the vast majority of contracts are open-ended (more than 85% of cluster employees have open-ended contracts), they allow for high employment stability in times of economic constraints.

In conclusion, the direct contribution of the ceramic cluster to employment represents a very significant percentage at national, regional and provincial level, as we can see in this image provided by ASCER.

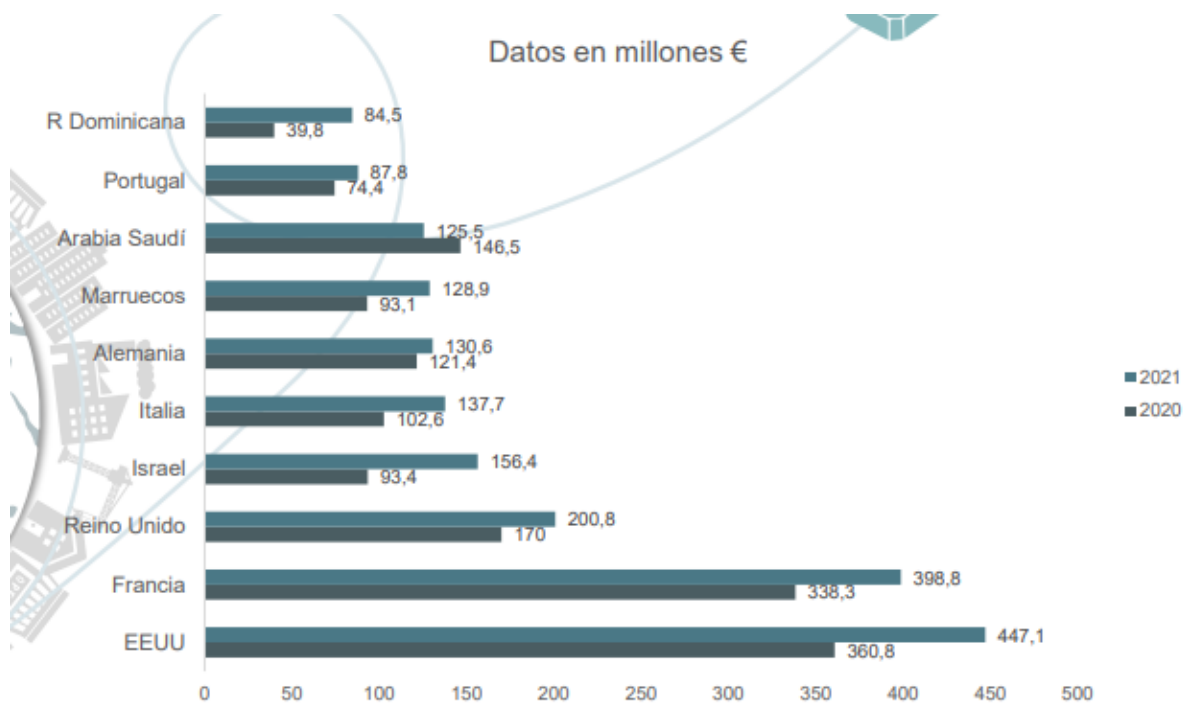
Figure 11: Contribution of the cluster to the Spanish ceramics sector



Source: Report ASCER,2020

As far as exports are concerned, the ceramics industry is by nature an industry dedicated to the export of its products, with products of high added value and volume. Specifically, the ceramics industry exported products worth 3,665 million euros in 2021. Of which 49% of exports went to European countries, with France being the main export destination. On the other hand, 51% of the sector's exports went to the international market, with the US market being the most important export market.

Figure 12: Main destinations for Spanish ceramic exports



Source: Report ASCER,2021

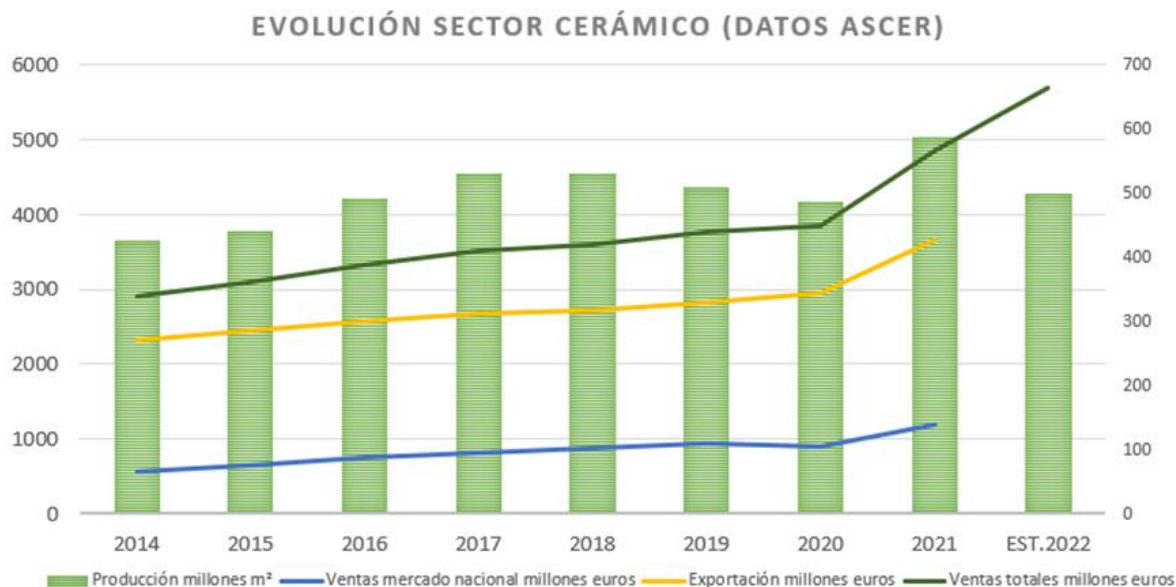
Likewise, the contribution of the Spanish ceramics sector to foreign trade means that exports represent 0.9% of total exports in Spain. The Castellón ceramic tile and flooring cluster stands out with 33% of the total value exported, ahead of sectors such as the chemical industry.

In conclusion, the export of ceramic products has caused a trade surplus in 2021, which amounted to 3,665 million euros, today with a positive evolution of 24.6% since 2020, thus contributing to reduce the Spanish trade deficit.

Finally, the turnover of the ceramics sector has been increasing in recent years due to the fact that it is a sector with a high production capacity.

In 2019, the sector's production fell due to the health, economic and social crisis of Covid-19, causing a drop of 3.8%. Despite this fall, the total turnover was not affected, and increased by 4.5%, showing an increase compared to previous years in the value of the ceramic product.

Graph 1: Evolution of the Spanish ceramics sector



Source: Own elaboration based on data from ASCER,2021

In terms of turnover, the industry has increased its revenues by an average of 5.1% per year since 2012. This evolution of its revenues shows the high growth potential of the sector and its importance for the Spanish, provincial and regional economy.

Table 1: Sector production and sales

Producción y ventas del sector	2014	2015	2016	2017	2018	2019	2020	2021	EST.2022
Producción millones m²	425	440	492	530	530	510	488	587	500
Ventas mercado nacional millones euros	574	643	746	824	870	939	901	1198	
Exportación millones euros	2328	2452	2570	2686	2727	2818	2941	3665	
Ventas totales millones euros	2902	3095	3316	3510	3597	3757	3842	4855	5700

Source: Own elaboration based on data from ASCER,2021

Thus, the total turnover for the year 2021 was 4,855 million euros, with a positive evolution of 26.4% compared to the last year and a positive contribution of 2.7% of the Spanish industrial GDP and 14.4% of the industrial GDP of the Valencian Community, according to the data provided by the latest report published by ASCER.

For this reason, the Spanish ceramics industry is one of the most important industries at national level, as it generates wealth and employment.

5. INNOVATION APPLIED BY THE SPANISH CERAMICS INDUSTRY

We are currently facing several problems due to the misuse of natural resources by people and companies, which lead us to rethink the business structure and business and production models. Current production models have led to unsustainable processes causing a series of unprecedented crises: economic, industrial, financial and environmental.

One of the most worrying issues is the environmental crisis. Climate change is producing an increase in the earth's temperature, due to the excessive use of fossil fuels, irresponsible use of soils and massive deforestation of forests, causing the emission of high quantities of gases that are favouring the greenhouse effect. (ASCER,2021).

In response to this situation, public bodies have established regulations to limit pollution levels, penalising companies that exceed the established limits and favouring those companies that comply with the established legislation with tax benefits and economic and social advantages. For this reason, many companies have decided to take corrective measures to try to slow down and reverse climate change. Obtaining social recognition for compliance with green strategies, which can help them to gain advantages over competitors and offer an honest vision towards the planet and the customer, who is increasingly aware of the need for products that are respectful of the planet.

This shift towards sustainability policies is going to be very difficult unless these strategies are fully integrated by all members of the organisations, as this implies a cultural change of business activity.

The main problems that may arise in adapting to this change include the following:

- There are organisations that only do it for image reasons, because they see that sustainability does not bring tangible benefits or perceive environmental strategies as a cost without benefits.
- It can also happen that incorrect implementation can lead to employee resistance or difficulties in accepting new changes.
- Having a short-term vision of business objectives.
- Thinking that environmental strategies are a high cost and will not result in benefits for the company.

- Fear of the unknown, i.e. fear of failure or failure to implement the strategy.

It should also be noted that the use of renewable or green energies can end up being harmful to the planet. For example, the automobile industry has promoted the use of electric cars to eliminate fossil fuel transport. But here the problem arises and it is that if we take as an example the battery of the mobile phone that in a period of 3 to 4 years its capacity is significantly reduced. This raises the following problem: if an electric car's batteries account for half of its cost, we must assume that after 3 or 4 years its autonomy will be limited. Therefore, the battery materials will have to be changed from time to time, and if they cannot be recycled, the pollution of the planet will increase, so the use of electric cars may not be suitable for carrying out a green strategy, as they will not achieve the sustainability they are looking for.

For this reason, it is necessary to analyse the pros and cons of renewable energies as their implementation in the future will be beneficial for the planet and will help to preserve it.

Focusing on the Spanish ceramics industry, the production of ceramic tiles, like any other type of product of industrial origin, has an environmental impact throughout its production cycle, i.e. from the extraction of the raw material to the final product. Therefore, understanding the impact is essential to improve processes and reduce pollution. As we have been able to observe in the studies published (ASCER,2021), the ceramic tile industry uses a large amount of energy for its production processes, from the extraction of ceramic clays to the final product. In particular, the firing and drying production processes consume the most energy. In order to reduce this energy consumption, ceramic companies have introduced processes to improve their supply logistics.

We are now going to analyse the strategies introduced by the ceramics industry and the benefits of their introduction.

In order to reduce this energy consumption, ceramic companies introduced natural gas and electricity to their production processes. Thus generating a reduction in the energy used, representing more than 20% of the production cost of ceramic tiles. (CIRCE, 2021).

Ceramic companies have also been encouraged to focus their research objectives on the introduction of new production processes to decarbonise.

Another change introduced by the ceramics companies to achieve greater sustainability in their production processes was the reduction of water in their production processes,

managing to reduce water use by 50% in the last 20 years. It has also managed to completely reduce the discharge of wastewater.

This improvement implies a reduction in the investment in municipal infrastructure that would be necessary to manage the discharges, thus contributing to the overall sustainability of the system.

Nowadays, greater importance is being given to strategies that aim to reduce the use of materials and their contamination. Thus, ceramic companies have made investments to eliminate polluting particles from their production processes by means of air filters. In addition to the correct storage of raw materials in closed places so that harmful particles are not transported to the population. (Fundación Repsol de Transición Energética, 2022).

Finally, thanks to these measures, carbon dioxide emissions have been reduced. Although, with the introduction of the different strategies, a reduction in pollution and more sustainable products has been achieved, companies should continue to research new production processes to reduce emissions.

5.1. ENVIRONMENTAL PROBLEMS CAUSED BY THE CERAMICS CLUSTER

The ceramics industry is one of the most productive sectors at present, having an exporting character that has a positive impact on the Spanish economy.

Although it is a benchmark industry and generates great economic value, its productive activities have an environmental impact, producing changes in the environment and in the surroundings where its activity takes place.

For this reason, we are going to analyse the impact of the productive activity carried out by the ceramics industry and how it affects the environment, since from the collection of raw materials to the final product it generates various pollutant emissions that affect the planet and people.

Firstly, in the process of preparing raw materials, the most frequent emissions that usually occur is the dispersion of dust, due to the fact that there are no systems in place to prevent this dispersion. This dispersion contaminates the work space, causing workers to inhale these dusts, which negatively affects their health, as the dust that are released from this process carry polluting materials due to the origin of the raw materials.

The next production process is the atomisation of the raw materials, in which hot gases are produced that carry the finer material out of the product and are transported to the outside.

In the pressing process, wet dust is usually dispersed, usually produced by the transport of the raw materials, pressing and brushing. Once the product has been pressed, the parts are dried and at this stage, water vapour and dust are emitted due to broken parts or incorrect brushing.

After pressing the product, the enamelling process begins, which is a process that can produce two types of emissions: wet emissions due to the use of water or dry emissions where there is a greater emission of materials into the atmosphere. The dust emitted in this process is very toxic due to the chemical composition of the materials used.

Finally, the firing process also releases polluting particles because the material is fused at high temperatures, sending polluting gases such as fluorine and solids such as lead, among others, into the atmosphere.

Apart from the emissions we have already mentioned, other types of pollution are also generated, triggered by the production process and the materials used.

Among the polluting effects that are produced, we would highlight above all the generation of wastewater due to the production of ceramics, as the production process produces ceramic dust and products that settle in the water, causing water pollution. This wastewater usually contains sulphates and traces of heavy metals.

Other waste generated by the ceramics industry is inherent waste, including scrap, glass, sand and products that have been broken during the production process, which are the most numerous wastes generated by this industry. Some of this waste, after use, can be recycled and have a second life. On the other hand, there are others that cannot be recycled and damage the ecosystem, as we cannot give them another life.

Finally, another activity within the production process that generates pollution, especially organic resources and other resources such as wood, paper and cardboard, is the packaging and transport of the products.

After seeing the different problems generated by the ceramic production process on the environment and people, the ceramic industries have decided to introduce and apply corrective measures and best practices to reduce these negative impacts, especially influenced by the pressure exerted by public organisations and people, who are

increasingly aware and informed about renewable energies and cleaner production processes.

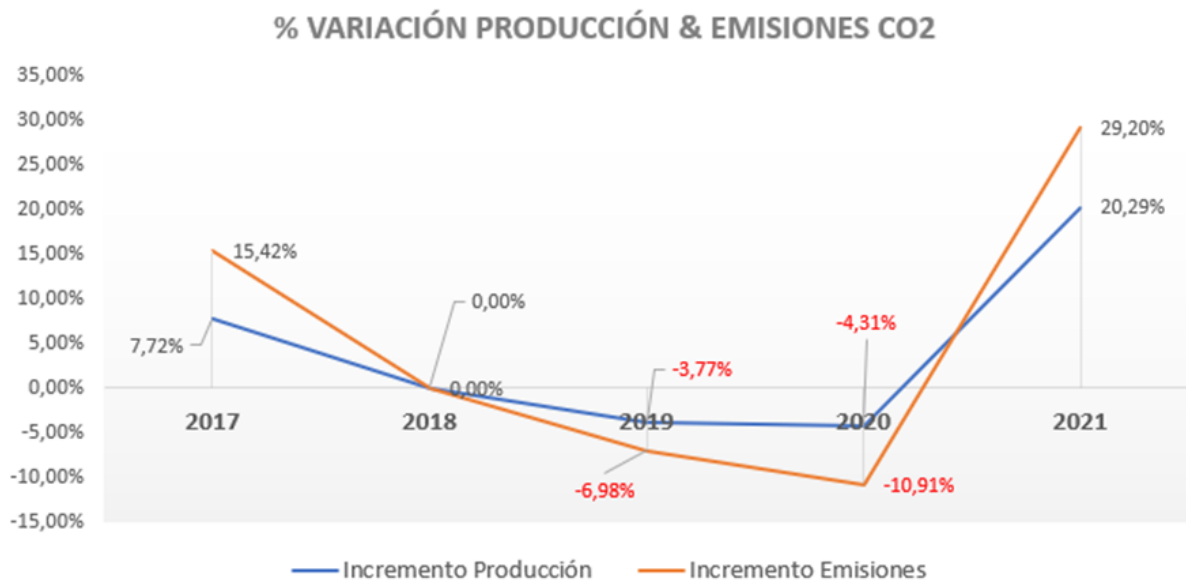
Among the measures that the ceramics industry can introduce to reduce the impact it generates in its production process are the following:

- Improve extraction systems, filters and storage centres to prevent the emission of dust particles. These emissions usually occur in the handling and storage processes of the material used in the ceramic production process.

The introduction of these improvements can have a positive influence on reducing the emission of polluting particles, being very effective in the majority of cases in which they are applied.

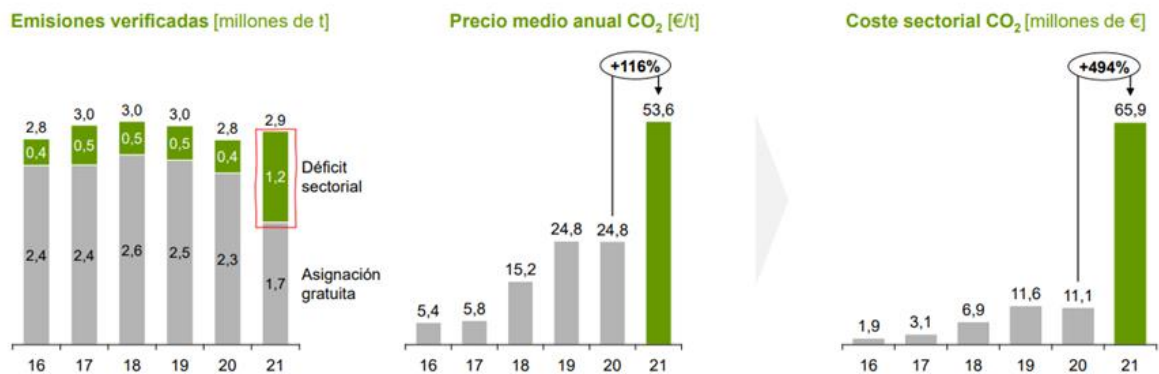
- Reduction of pollutant gas emissions, which can be achieved through the introduction of new methods that promote the use of raw materials with a more favourable chemical composition for their production, giving off fewer toxic particles. In addition to using selection and extraction processes that are less aggressive towards the environment.
- Reducing energy consumption by recovering the heat generated in ceramic kilns. Helping to reduce greenhouse gas emissions.
- Introduce less noisy processes in the production stages or implement soundproofing techniques.
- Adding new machines that work with renewable energies in the most polluting production processes.
- Reduce dependence on natural gas and energy consumption, focusing production on other types of renewable energies and reducing the value of those currently used, so as not to suffer from price variations and not to compromise production, as is currently happening due to the war in Ukraine.

Graph 2: Change in production and CO2 emissions



Source: Own elaboration based on data from ASCER,2021

Graph 3: Comparison of emissions and costs



Source: ASCER,2021

The graph shows the variation in production and CO2 emissions produced by the Spanish ceramics industry. There is a notable increase in the year 2021, together with a reduction in the free allocation, which means an increase in CO2 emissions, a circumstance that has worsened in 2022.

At present, ceramics companies are responding to the growing need to improve production processes, reduce pollution and raise the quality of their products. As a result, it has prompted many ceramics companies to introduce departments in charge of product, company and employee quality management in order to achieve greater safety

in production processes. These departments play a key role in ensuring process safety and efficiency, as well as customer satisfaction.

In addition, to invest in research, to introduce new methods, new raw materials, less harmful to the environment and to analyse the current production process to detect possible defects in the production process and introduce improvements to reduce pollution.

5.2. ANALYSIS OF ENVIRONMENTAL STRATEGIES IN THE CLUSTER

The increased specialisation and proximity of companies in the Spanish ceramics sector has led to an increase in atmospheric pollution. For this reason, we must know the ceramic production process and the pollutant emissions that arise from it, in order to try to establish measures to reduce the negative effects and achieve a sustainable development of the ceramic industry.

Bearing in mind that ceramic tiles are the final product of the industry, we are going to analyse all the processes involved, from obtaining the raw materials to the final product.

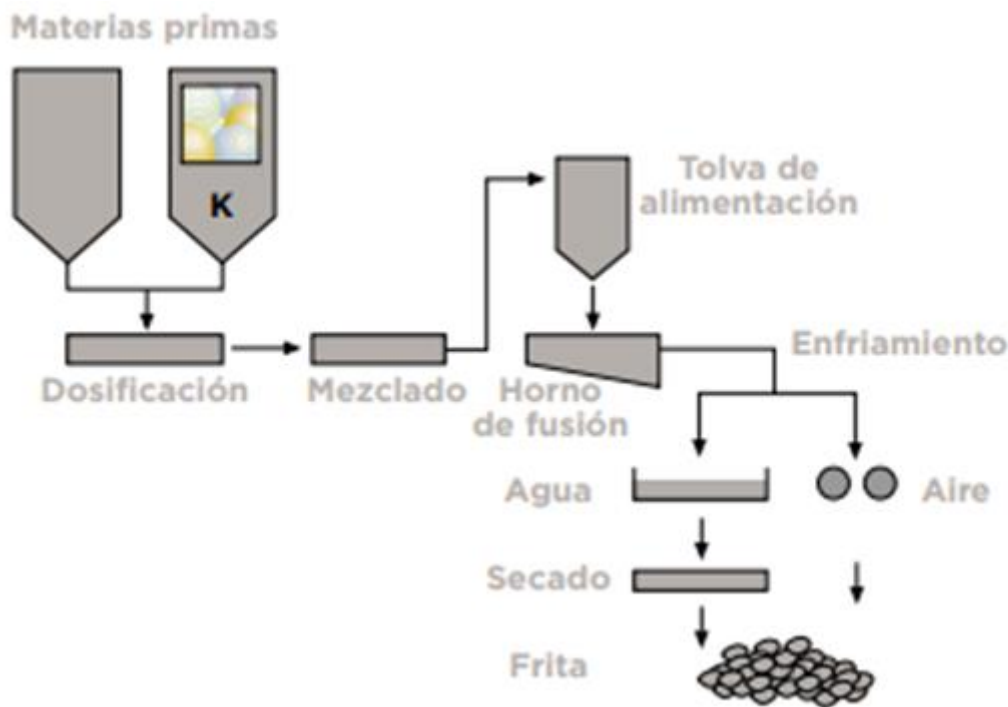
The first step is the extraction of ceramic clays in quarries. This process of clay extraction is an aggressive process for the environment and for the soil where it is produced, as this type of activity causes polluting particles generated by the transport, storage and handling of materials.

Thus, the emission of polluting particles in the extraction of clays in the open air benefits from the combustion of the machinery used and the transport of these once they have been extracted.

The second step in the tile production process is the manufacture of frits, glazes and ceramic pigments.

The production of these materials is obtained by melting raw materials in kilns at high temperatures (over 1300-1500 °C), for subsequent cooling.

Figure 13: Frit manufacturing process



Source: ANFFECC (National Association of Manufacturers of Frits, Glazes and Ceramic Colours)

In this production process, the type of polluting particles generated have the same chemical characteristics as the composition of the frit being used. In the melting furnaces, due to the high temperature, volatile elements are produced (such as boron, fluorine, sodium...), solid particles and pollutant gases from the combustion of natural gas.

Therefore, the ceramics industry is an industry that generates a large volume of atmospheric emissions due to the use of materials that easily disperse polluting particles, as well as having production processes that work by combustion, generating polluting gases and particles.

In this way, we can distinguish different pollutant sources generated by the ceramics industry. Such as that produced in the production of ceramic tiles, due to the dispersion of dust in the production plants (to reduce the dispersion of polluting dust, many companies use suction fans) and finally, we can distinguish the emission of polluting gases generated in the combustion processes of the materials, such as the drying and firing processes.

Due to the fact that pollutant emissions influenced by the productive activity of the ceramics industries are having a negative impact on the air and the population, it has

become necessary to implement an Atmospheric Sanitation Plan, which aims to establish general measures for the whole sector and specific measures for each sub-sector, in order to try to reduce pollution in this sector and make it more sustainable.

For this reason, a coordination committee has been created, made up of different stakeholders (such as politicians, industrial companies and citizens), in which the necessary measures will be established to determine the plan in a way that implicates all the people involved, as well as presenting the objectives in a clear way that contributes to the improvement of the sector.

This committee is responsible for analysing the production processes of the ceramics industry and the sources of pollution in order to detect where they occur and establish corrective measures.

As regards the corrective measures established, there have been two types of general and specific measures.

With regard to the general measures to be implemented throughout the industrial sector, it is worth highlighting the elimination of the most polluting fuels, the introduction of renewable energies, the application of tax benefits to companies that reduce their emissions and, finally, the regulation of the territorial concentration of potentially polluting activities.

On the other hand, specific measures have been introduced in the Ceramic Sanitation Plan for each company involved in a production sub-process for the production of ceramic tiles:

- In the extraction and transport process, some of the most important measures that have been introduced are the storage of raw materials that can be transported by air in enclosed or semi-enclosed areas, the sprinkling of clayey raw materials in tanker trucks and the limitation of the height of stockpiles, in order to be able to more easily control the emissions of polluting dust particles.
- In the manufacture of frits, glazes, pigments and ceramic coatings, measures are being implemented to reduce pollution. Among the measures implemented are: cleaning materials and particles at the kiln inlet, extracting gases coming out of the chimneys and promoting the use of renewable energies, reducing particulate pollutants in products.

Once the measures to reduce pollution in a ceramic company have been implemented, a monitoring programme must be established to control the compliance of the companies with the measures and quality standards established in the sanitation plan.

For this reason, the coordination committee should be in charge of taking continuous measurements of the pollution levels, in order to detect if there are companies that do not comply and penalise them if they do not comply. They should also see to what extent the established measures are helping to reduce pollution and correct or add new measures that will help to reduce pollution in the ceramics industry and allow for its sustainable development.

5.3. IMPLEMENTATION OF CORRECTIVE MEASURES

According to the study by the Professor of the Repsol Foundation, she defines the ceramics industry as thermo-intensive, due to an annual consumption of 1.4 TWh of electricity and 14.1 TWh of natural gas. This industry uses 7% of the gas consumed by the Spanish economy as a whole and 50% of the gas consumed by the Valencian Community as a whole.

Natural gas represents 91% of the energy used in manufacturing, and the remaining 17% comes from electricity. As far as gas consumption is concerned, furnaces and kilns account for 58% of gas consumption, the remaining 38% goes to cogeneration units and 5% to post-combustion burners.

The following figure shows the different stages of the ceramic process, highlighting the stages in which gas is consumed.

Figure 14: Ceramic production process



Source: ASCER,2022

After a decrease from 12 kg/m² in the mid-1980s, CO₂ emissions in the sector are now just below 6 kg/m².

Therefore, once we have identified the points in the production process where the ceramics industry produces more emissions and is more polluting, we proceed to analyse various measures that can be applied in the sector. The measures we will analyse are uncertain due to the fact that, in some cases, the entry of disruptive technologies is anticipated, which could change the future scenario as it is currently defined. As a result, we will conduct a review of the current state of technologies, focusing on the short term.

- Biomethane

From a technical point of view, biomethane could be directly applied in the processes of the Spanish ceramic industry due to its high level of purification as it can be supplied through the existing natural gas network.

Due to the interchangeability of the two gases, the introduction of biomethane as a gas substitute would be used in production processes as it is the conceptually simplest solution. It also has the benefit of being a locally available resource with very stable prices, despite having historically higher prices than natural gas.

This measure is competitive in the current environment, but faces significant challenges due to Spain's low production, which currently stands at 0.1 TWh. Although there is a projection of increased biomethane production in Europe, the amount of biomethane produced during these times will be only 30% of natural gas demand, indicating limited availability.

Based on the analysis, it is possible to conclude that in the short term it is not feasible for the Spanish ceramic tile sector to implement biomethane in its processes.

- Green Hydrogen

Bringing electricity to thermal uses through green hydrogen opens up great expectations.

But its use in furnace burners still has technical problems, due to increased combustion rates, high humidity of the combustion product and the formation of NO_x, a greenhouse gas.

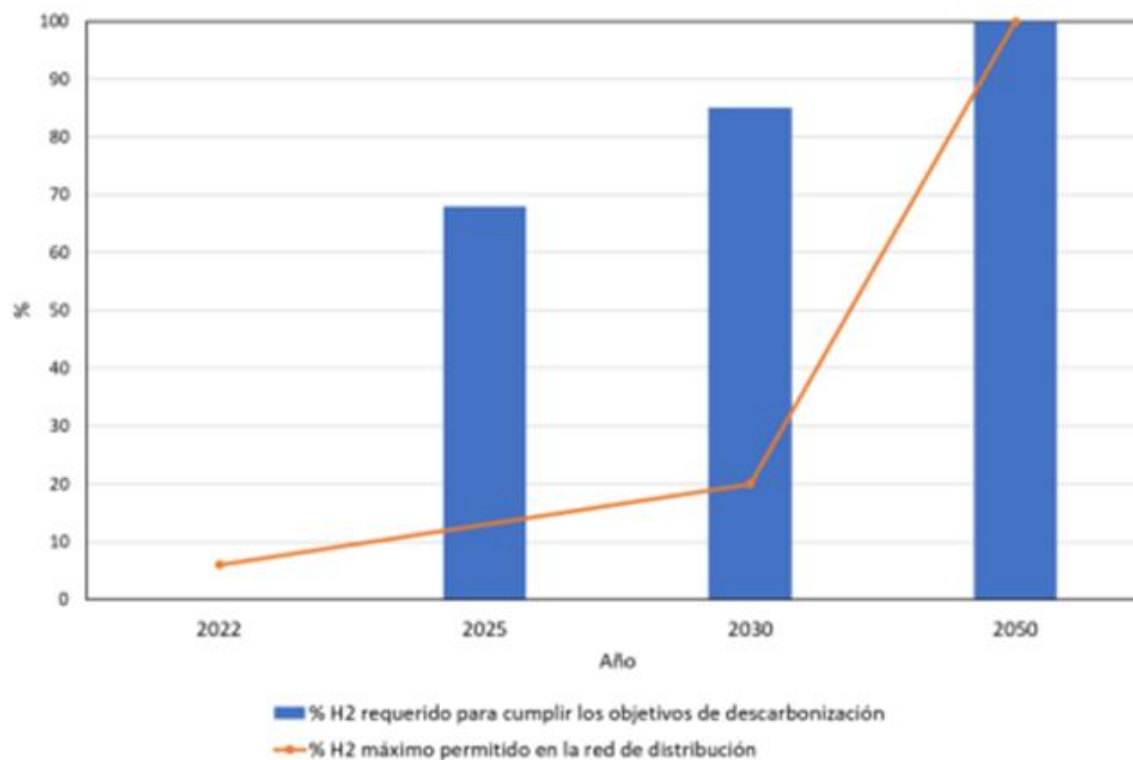
This is why green hydrogen is currently emerging as a technology to be developed, as there is no commercial deployment of its production and there are currently few natural

gas networks that can transport it to the various consumption points. Forecasts indicate that the use of green hydrogen may become more profitable than the use of natural gas, although this will depend on the specific evolution of hydrogen prices.

Consequently, it is foreseeable from an economic perspective that support and financing mechanisms will be needed to make its use in industry economically viable.

The current availability of green hydrogen for the Spanish ceramics industry will not be a reality that will enable its decarbonisation, as can be seen in the following figure from the report prepared by CIRCE.

Figure 15: Comparison between the green hydrogen required to meet the targets and the maximum allowed.



Source: CIRCE,2021

- Electrification

The first thing that is striking about the electrification measure is the reduction of CO2 emissions. The application of this measure in industry could result in a saving of around 2.6 million tonnes of CO2 per year, counting only the reduction in the substitution of gas in the process, since approximately 90% of the energy is thermal and therefore polluting.

This measure aims to directly electrify the stages of the production process where there is a greater need for energy.

The alternative to the wet granulation and atomisation process is an electrified dry process, which has shown that, despite its technical feasibility, it requires further development and specific study in each case to achieve results with similar quality characteristics. In other words, it is not a direct technology replacement and requires modifications to production processes.

Introduction of the dry granulation process as an alternative to the wet granulation and atomisation process. Despite its technical feasibility, it requires changes in production processes and does not directly replace existing technology.

The drying stage offers the greatest potential for replacing conventional roller dryers with electric systems, but due to the cost and maturity of the technology, the microwave kiln is the most advantageous option. Even if this stage of the process were to be electrified, the reduction in emissions would not be as significant as if it were achieved at the cooking or atomising stage.

The firing process has been found to be one of the biggest barriers to the adoption of substitutes such as electric resistance kilns and microwave kilns. Since the hybrid kiln technology (electric resistance and microwave) mentioned above is still under development, switching to electric heating would require a significantly different kiln design.

In conclusion, these measures imply important changes in factories, but electricity prices have to be taken into account, as they are currently much higher than natural gas prices. It should also be noted that these technologies are not yet advanced enough to be used in the ceramic tile industry.

Figure 16: Current technological developments



Source: ASCER report decarbonisation, 2022

- CO2 capture

Instead of preventing the formation of CO₂ in production processes, an additional measure that can be applied in the ceramic industry is to capture the CO₂ already present. Technologies to capture the gas have existed for some time, but due to the low concentrations of CO₂ in the exhaust gases and the insufficient solutions available, this is a measure that is still under development.

As regards the ways in which CO₂ can be captured, there are two different options. One is post-combustion capture and the other is to capture directly from the environment the CO₂ that has been released during the production process. In turn, due to the scarcity of domestic natural gas and oil resources, there is limited storage capacity.

In conclusion, once the different corrective measures that can be applied to the ceramics sector have been analysed, we can state that they still need a great deal of technological development to be applied.

Once they have been developed for application in the ceramics industry and their viability has been checked, we will be able to analyse whether the effect produced is satisfactory and manages to reduce pollution levels.

After examining the possible corrective measures that can be implemented in the sector, we are going to analyse the environmental problems that have arisen in the Spanish ceramics industry and the solutions that have been provided or can be provided in the future.

Table 2: Summary table on problems and possible solutions

PROBLEMS	SOLUTIONS
Emission of particles and toxic gases during firing	<p>The ceramic industry has implemented measures to reduce the emission of particulate matter and toxic gases, such as the use of gas filters and the optimisation of firing processes to reduce firing temperature and time, which has allowed it to become more efficient and less polluting.</p> <p>In the future, more efficient and cleaner combustion technologies could be further implemented, such as carbon capture and storage, implementation of energy recovery systems and optimisation of the composition of raw materials used in the manufacturing process. Moreover, alternative fuels, such as green hydrogen, could be introduced to further reduce pollutant gas emissions.</p>
Generation of solid and liquid waste (such as chemicals and particulate pollutants)	<p>The ceramic industry has implemented waste management practices, such as waste separation, reuse of materials and implementation of waste treatment systems.</p> <p>To improve and reduce the generation of this waste, companies could implement measures that contribute to reducing waste generation, such as the development of new manufacturing processes that generate less waste, i.e. the implementation of eco-efficiency programmes that further reduce the amount of waste generated, the implementation of circular economy systems and the promotion of the use of recyclable materials and packaging.</p>
Excessive water consumption in production	<p>The Spanish ceramics industry has implemented water management practices that reduce water consumption in production, such as the recycling of water used in the manufacturing process and the implementation of rainwater harvesting systems. In the future, wastewater recirculation and treatment systems could be further implemented so that wastewater can be reused at different stages of the process, minimising waste.</p>

<p>Pollution of water and soil by liquid waste discharges</p>	<p>The Spanish ceramics industry has implemented liquid waste management practices that comply with local environmental regulations, such as the proper disposal of liquid waste and the installation of wastewater treatment systems. In the future, measures could be further implemented to reduce the amount of liquid waste generated, such as the use of wastewater recycling and reuse techniques. In addition, more advanced and efficient liquid waste treatment technologies could be further researched and developed.</p>
<p>Noise generation</p>	<p>The ceramics industry has implemented noise management practices, such as the use of soundproofing equipment, the installation of noise barriers and the implementation of production schedules that reduce noise levels during the rest hours of the nearby population. In the future, measures to reduce noise in production could be further implemented, such as the development of new production technologies that generate less noise or the use of new, quieter materials in manufacturing processes.</p>

Source: *Elovn compilation based on data from from the Repsol Foundation chair on energy transition,2022*

6. CONCLUSION

The Spanish ceramics sector is highly relevant worldwide, and within Spain, the Castellón de la Plana ceramics cluster stands out as a benchmark in terms of innovation, quality and productivity. The concentration of companies in this region has allowed the ceramic sector to expand in terms of data and infrastructures, generating significant benefits at national level. Internationally, the Spanish ceramics sector is recognised, although it faces competition from countries such as China and Brazil.

Today, the collaboration between cluster members and their ability to learn gives them the opportunity to take advantage of market opportunities and stand out in terms of resources, skills and professional talent. Despite the constantly changing environment, the cluster continues to continuously improve in order to address emerging threats. Throughout its history, it has faced crises and other challenges, but the companies, with the support of institutions, have managed to overcome them and maintain their competitiveness both nationally and internationally.

From my point of view, the current situation facing the ceramics industry is complicated because, as we have developed throughout the work, it is an industry that contributes significantly to greenhouse gas emissions, although measures have already been introduced to achieve decarbonisation in the process, it is not enough to reduce it, so the industry must continue to implement and research new processes that contribute to reducing gas emissions, as alternatives to natural gas we have seen green hydrogen, electrification or biomethane, among others. In addition, the conflict in Ukraine has resulted in limited supplies of raw materials and energy, which are essential for ceramics production. This has led to an increase in production costs and a reduction in the production capacity of ceramic manufacturers.

Despite the challenges associated with ceramics production, the ceramics sector is making great efforts, introducing new technologies at the production stages, preparing employees better, investing more in R&D and collaborating closely with institutions that provide new ideas and enable it to develop its processes. For this reason, technological innovations are the key for the ceramic sector to remain a leader, as advances in materials and production processes, as well as in the automation and digitalisation of processes, will allow for greater efficiency, precision and flexibility in ceramic production.

Once the analysis of the ceramics sector has been carried out, we can affirm that we have managed to fulfil the objectives previously set, as we have carried out an analysis

from the beginnings of the cluster to the present day, emphasising the problems faced by the cluster and the possible solutions that can be implemented.

As for some limitations or issues that have not been addressed in this work, and that I would like to see in future works are the feasibility of changing raw materials in the production process (such as clay and kaolin), in order not to have as many problems as happened in the political conflict in Ukraine, the use of technologies such as 3D printing or the use of new forms of promotion and marketing to raise awareness and better position the brand TileofSpain. These topics are very interesting because, as we have seen throughout the work, the ceramics sector is a sector with many avenues for research and improvement, which, if carried out, will contribute to the improvement of the sector.

Finally, after the analysis carried out on the Spanish ceramics sector and specifically the ceramic cluster located in Castellón, I have been able to observe the commitment they have acquired over the years to achieve greater sustainability in their processes and their history of innovation, in order to better position themselves to face the challenges and continue to be a leader in the global ceramic industry.

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