ESTABLISHING MEASURES TO ENCOURAGE INDUSTRIAL SYMBIOSIS IN THE CERAMIC SECTOR

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1. ABSTRACT

The concept of a circular economy has burst into society in general and also duly into production processes. The circular economy assures sustainable growth given that resources are used in a more intelligent and reasonable way. The application of industrial symbiosis activities allows us to share resources between companies in a sustainable manner and therefore to move closer towards a circular economy.

Information is unavailable on initiatives in Spain aimed at fostering industrial symbiosis processes. However, there are companies that share resources, and have been doing so for years, performing activities that were generated spontaneously by responding to specific needs.

This paper seeks to foster the implementation of industrial symbiosis in the Spanish ceramic sector. In order to do so, firstly, the results of analysing the processes currently sharing resources in the Castellón ceramic cluster are set out. Next, an overview is presented of the processes that are technically viable and that could lead to the establishment of new synergies between the ceramic sector and other industrial sectors located in the area.

The need for tools that allow us to foster the use of shared resources is highlighted, indicating those that currently exist and those that are being developed, which may be used in the near future by companies interested in incorporating the circular economy into their production processes.

2. INTRODUCTION

During the last few years, the European Commission has put a series of initiatives into place with the aim of promoting the transition from the current linear economic model (make-use-dispose, implemented in most activities) towards a circular model, whose main objectives are: optimising the use of resources and avoiding and/or minimising the generation of waste. Accordingly, one of the perspectives from which this transition towards a circular economy can be driven in the industrial sphere is that of industrial symbiosis [1], [2].

The first and best-known example of the establishment of symbiotic networks is found in the municipality of Kalundborg (Denmark) [3]. In this case, symbiosis originated from the scarce availability of underground water and the need for a source of surface water that, once identified, became a key part of the resource exchange network. Symbiosis in Kalundborg arose from private initiative with the aim of achieving business objectives such as reducing costs, increasing revenue, business expansion and long-term security.

During the last few years, industrial symbiosis processes have been encouraged through the development of tools that allow us to analyse and foster interrelations between industrial systems, such as: Life-cycle Assessment (LCA), Resource Flow Analysis (RFA), Process Flow Diagrams (PFD), By-products Exchange or Market, Industrial Metabolism and Environmental Economic Analysis.

In some countries, such as the United Kingdom, there are programmes that foster connections between industries and the creation of new opportunities, such as the "National Industrial Symbiosis Programme" (NISP).

In Spain there have been development initiatives for industrial symbiosis projects on a regional level. In a study performed in Cantabria, Ruiz et al. [4] highlight the need to use tools to process information. The Basque Country is one of Spain's autonomous communities that has promoted this initiative the most, promoting projects to demonstrate the reuse of materials [5]. In Manresa (Catalonia), a symbiosis implementation project also began in an industrial area in 2015 ("Manresa en simbiosi" [6]).

The present study was carried out in the context of the European Project SHAREBOX, the main aim of which is the development of a tool for the flexible management of resources shared between companies, as well as the identification of new synergies. Within the framework of this project, a series of tasks were carried out aimed at identifying synergies within the ceramic tile manufacturing industry located in the Castellón area, the results obtained being presented below.

Lastly, information was gathered on new potential industrial symbiosis processes that could be generated between the ceramic tile manufacturing sector and other manufacturing sectors, with the aim of energising industry on this issue.

3. INDUSTRIAL SYMBIOSIS IN THE CERAMIC TILE MANUFACTURING SECTOR IN CASTELLÓN

The Spanish manufacturing of ceramic tiles is concentrated in the province of Castellón, where about 200 companies are located (126 ceramic tile manufacturers, 24 manufacturers of ceramic glazes and frits, 42 companies manufacturing machinery and 8 suppliers of raw materials), the majority of them being small and medium-sized companies.

With the aim of identifying the industrial symbiosis processes that currently take place in the ceramic industry, interviews were carried out with various industry stakeholders. The detected synergies are schematically illustrated in figure **1** and set out below, with more information available in the publication by Bou et al. [7].

One of the most widespread and best-known industrial symbiosis processes among companies in the industry is the *reuse of sludge from the glazing process (Glazing Sludge: FE) in the preparation of ceramic bodies*. This action emerged due to technical and legal necessities and was developed at first by drawing up point agreements between companies due to the significant economic savings obtained. These point actions became generalised and were formalised by the signing of a collaboration agreement between the tile manufacturers' association ASCER and the Autonomous Government of Valencia. As a result, the spray-dried powder producers received sludge from the glazing departments of ceramic tile manufacturers, as well as the waste materials generated before the firing stage (unfired tile scrap: TCR). Not all unfired scrap can be incorporated into the production process in the sprayer dryers due to its different nature; when this occurs, it is treated as waste. With regard to the ceramic frit and glaze manufacturers, in some cases, there are agreements with the spray-dried powder producers, enabling them to send glaze sludge (FE) along with the frit quenching water (A). When these agreements do not exist, these materials are handled as waste.

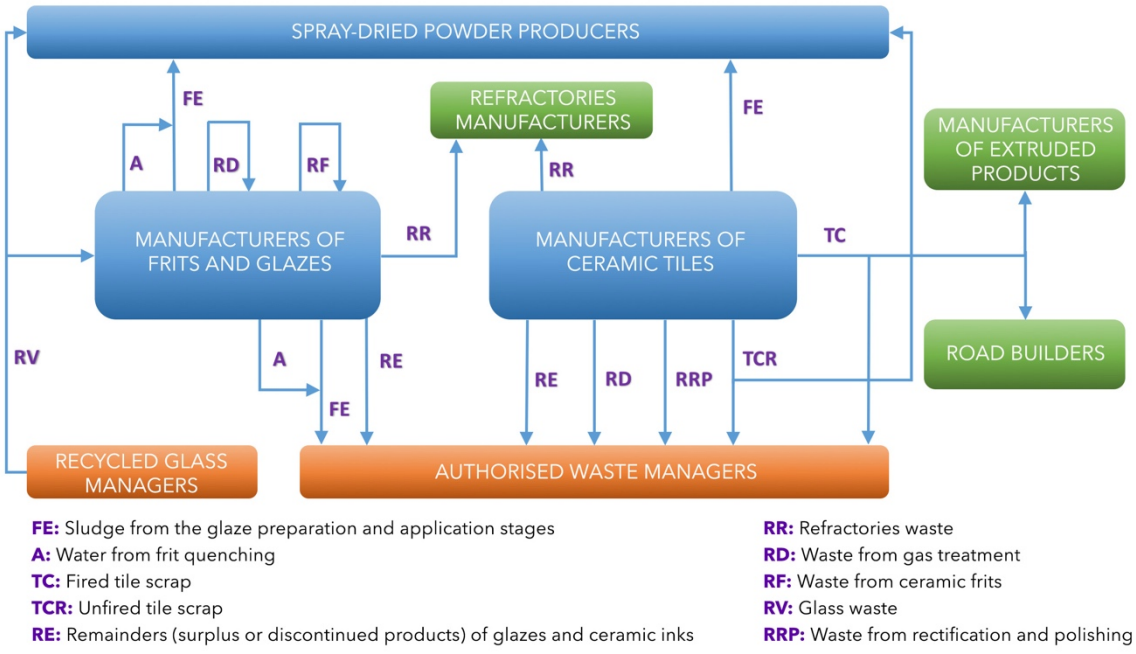

Figure 1. *Industrial symbiosis processes detected in the ceramic industry.*

Another industrial symbiosis process being carried out between the ceramic sector and other sectors is *the use of recycled glass (RV) for the manufacture of frits, engobes, ceramic glazes* and, in some cases, it is also used for the manufacture of ceramic bodies or tesserae. The creation of recycled glass handlers has allowed the implementation of this product as a high-quality raw material at a competitive price, given that it has solved previously existing problems relating to consistency and quality in supply.

Another industrial symbiosis process detected is the use of *fired tile scrap* (TC) (finished ceramic tiles that are not saleable) as *aggregate for roads* although nowadays a large amount of this waste is sent to waste managers. In some cases, when the fired tile scrap is generated near to *manufacturers of extruded products* it can be used in the manufacture of this type of products as chamotte. However, due to the manufacturers of extruded products being relatively scarce in the Castellón area, this process is not very widespread.

Lastly, another smaller-scale symbiosis process, due to the lower amount of waste generated, is the use of refractory waste (RR) by the refractories manufacturers themselves. In this case there is a commercial relationship between both companies that facilitates the symbiosis process.

At present, frit manufacturers have modified their process with a view to recovering waste from melting furnace gas treatment (RD) and frit wastes (RF), generated during the manufacturing process, which cannot be marketed. In the case of ceramic tile manufacturers, wastes coming from gas treatment (RD) of the firing kilns and rectification and polishing wastes (RRP) are landfilled.

Both frit and ceramic tile manufacturers, although the latter to a greater extent, generate waste from discontinued products. These remainders are mainly glazes and ceramic inks (RE) and they are sent to authorised waste managers for disposal. However, in regard to wastes from ceramic inks, it is worth mentioning the study submitted by the company Zschimmer & Schwarz at CEVISAMA 2017, which received the 'Alfa de Oro' award for the development of a recovery and evaluation system for traditional screen printing inks for use in ceramic compositions adapted to new technologies.

There are other waste materials such as cardboard, plastic, used oils, etc., that, as they are present in all industries, have not been considered.

All of the synergies mentioned up until now have been focused on materials. However, in the ceramic sector, allowing facilities to be used for processing certain products has also been identified as an application of industrial symbiosis.

With the aim of establishing possible future industrial symbioses, ideas have been actively gathered through personalised surveys carried out within the framework of the SHAREBOX project. A literature search was also carried out on possibilities for symbiosis with companies belonging to other industrial sectors.

The synergies found between companies have been sorted into three types, according to the criteria of Ruiz et al. [4]:

Synergies of **mutuality**: These opportunities consist of the use/shared use of common services, facilities or infrastructures by the companies.

They include mainly logistic and service issues. In this case, the companies would be ready to share land, transport, separate collection of waste (especially cardboard and plastic), etc.

Synergies of **substitution**: These opportunities imply that the waste flows of one company become the input stream for another.

There is a huge amount of literature on the technical viability of substituting raw materials used in the manufacture of ceramic tiles. In fact, it is possible to call the ceramic sector a waste flow sink sector. The raw materials include:

- Use of *wastes from the exploitation of marble* [8],[9] *and granite* in the manufacture of ceramic glazes and bodies.
- Use of *ashes* from various processes (coal-fired power stations [10], urban waste incinerators, rice husks [11], etc.), as a source of silica for the manufacture of ceramic frits and bodies.
- Use of *by-products from the metal smelting process* in the manufacture of ceramic tiles, studied in the FOUNDRYTILE project [12], [13].
- Production of *pigments* using *wastes* [14].

In addition, the opposite case can also occur. That is, the ceramic industry could be a source of waste flows towards other industries. For example, we could mention the following:

- Use of *wastes from treatment of acid emissions* by kilns manufacturing ceramic tiles, mainly in the metallurgy sector [15].
- Use of *ceramic tile wastes* as aggregates in the manufacture of *structural concrete* [16].

Synergies of **genesis**: These opportunities are related to the creation of a new activity to meet the reuse needs of any flow or company. In this case, the following have been identified:

- Creation of *waste treatment companies* specifically for the ceramic industry, which guarantee a consistent supply and composition. This would be the case for companies that mill fired tile scrap and dry sludges. It would also be the case for other intermediary companies dedicated to treating a particular waste (for example, an oxide used in the ceramic sector, such as alumina) that nowadays is not used because it is not homogeneous or because it is wet.
- Creation of companies specifically for *making ceramic products whose main raw materials are waste products* from the industry itself or other industries, one example is the LIFECERAM project, [17],[18].
- Design of *alternative uses* for discontinued ceramic tiles that are still in stock, LIFE CERSUDS project [19].

4. METHODS FOR THE ESTABLISHMENT OF NEW SYNERGIES

At present in Spain, the most widespread tool for reusing waste material flows is made up of databases spread over various regions and waste managers. These bases gather the information on available wastes, but it is fairly tedious to find possible synergies as the available information is scarce and cannot be consulted automatically.

Outside Spain, the methodology that has proved the most suitable is the use of the SynerGie® program, developed by the company International Synergies Limited (ISL) [20]. This software is being used globally in nine countries. The program allows the gathering of information on the resources available at a facility (not just the wastes generated); in addition, it identifies synergies between various user companies.

This methodology has been imported and used in the establishment of synergies between companies in the ceramic sector and others, through two workshops within the SHAREBOX project.

The developed workshops follow an identical system and aim to identify synergies between companies that provide industrial symbiosis processes. The methodology is based on the exchange of information in an orderly and defined manner with the help of a workshop director and one moderator per table. The director organises the session and is in charge of getting it started along with the moderators. The participants are assigned to tables, set up in the shape of a circle, with six people at each table, following certain logical criteria such as: not seating people from the same company at the same table, avoiding putting competing companies next to each other, etc.

It must be taken into account that the resources to consider are not just materials, but also those indicated below:

- **Materials:** wood, plastic, food waste, waste from electric and electronic devices (RAEE), metals.
- **Specialisation:** ISO 9000, ISO 14000, OSHAS 18001, best practices.
- **Capacity:** equipment, test laboratories and facilities that are not often used.
- **Logistics:** transport, warehouses, land.
- **Water and energy:** residual heat, water sources, process water.

Next, using a card system (**Figure 2**) each attendee indicates the resource(s) they have available, to later mention these resources at each table and gather the people/companies that are interested in any of them. The information included on the cards is circulated around the various tables so that all participants can see all of the resources recorded. Likewise, information is gathered on resources that a person/company wants and they proceed in the same way as before.

I HAVE in table n° 6	I WANT		
Name of Company	Table n°	Name of Company	Amount of materials
The Mammoth Museum Ltd	4	Tuskers Luck Ltd	2,000 tons
Name of participant	2	Spartacus Reclamation Ltd	5,000 tons
P. Flintstone			
I have			
Bloques de piedra			
Amount of materials			
10.000 toneladas			
Location			
Wolverhampton			
Requirements (frequency/duration)			
2013 March weekends during 10 weeks.			

I HAVE in table n° 2	I HAVE		
Name of Company	Table n°	Name of Company	Amount of materials
Land Network International Ltd			
Name of participant			
Emma Cheetham			
I have			
Recuperación de tierras.			
Amount of materials			
1 sitio de 4-6 hectáreas			
Location			
Dentro de un radio de 15 millas de Bilston			
Requirements (frequency/duration)			
By the end of October 2012. Potentially a full-time contract.			

Figure 2. *Cards for resources that I HAVE (Left, green card) and for those that I WANT (Right, yellow card).*

After the workshop finishes, the information collected is put into the SynerGie® program, which allows it to establish the synergies found and return this information in the form of a report that is delivered to the participating companies. Afterwards, the synergies found are monitored with the aim of fostering their implementation. These actions are also recorded in the tool.

The methodology described was used in four workshops within the framework of the SHAREBOX project. The workshops took place in three countries: Spain, with two, Turkey and the United Kingdom.

In Spain, the first workshop took place in Nules with the support of the local City Council (**Figure 3**). The aim was to find synergies within the industrial estates of Nules, mainly "La Mina", where the companies participating in the Project were located: KEROS, S.L., KERAFRIT S.L., GUZMAN GLOBAL and IBÉRICA DE SUSPENSIONES, S.A. (ISSA).

Figure 3. *Photographs of the workshop in Nules. Left: Mayor and Councillor of the Nules City Council; Centre: participants; Right: work table.*

The second workshop took place in the Castellón Chamber of Commerce and was attended by companies from various sectors from the province of Castellón and Valencia (**Figure 4**).

Figure 4. *Photographs of the workshop in Castellón. Left: Workshop presentation; Centre: participants; Right: work tables.*

Table 1 shows the results of the workshops carried out within the project framework. As can be observed in the workshop in Nules, only two possible synergies were found between the companies of the Nules industrial estate, due to the number of participating companies being very low. When the number of participants increases, so do the number of synergies found. For example, the workshop in Castellón reached a number of synergies similar to those found in the other countries.

Country	*Spain*		*Turkey*	*UK*
Date	23/06/2016 (Nules)	21/07/2016 (Castellón)	17/11/2015	19/10/2016
Companies	7	22	50	16
Resources	77	152	336	92
I have	40	93	166	58
I want	37	59	170	34
Ideas generated	2	173	572	137

Table 1. *Results from the workshops carried out within the project framework.*

If we look closely at the results obtained, we find that the synergies found between the companies of the Nules industrial estate were the joint purchase of energy and management of waste collection. The follow-up for these synergies showed the existence of a specific problem that arises when they are put into practice, given that the administrative management is complicated in this situation, especially if there are more than two companies involved, as may occur with the establishment of a common day for separate waste collection (cardboard, plastic, used oils etc.) on an industrial estate. This is due to the frequency with which waste is generated being dependent on the type of industrial activity.

Regarding the synergies found in the Castellón workshop, the majority related to the use of wastes by other companies. A series of problems arose, which are listed as follows:

- Increased cost for treatment and transporting wastes for their use by another company.
- Need for investment for separate waste collection.
- The use of wastes implies the procedure of companies declaring themselves waste managers.
- Disagreements on the price for using a company's waste.

5. DEVELOPMENT OF THE SHAREBOX TOOL

One of the objectives of the SHAREBOX project is the design of an evolved tool that includes the functionalities of the SynerGie® program but which also improves the identification process of synergies so that these can be carried out automatically, without the need to organise in-person workshops with the user companies, with the resulting savings in time and logistics.

Part of the results of the study carried out up until now are presented in the article published by Capelleveen et al. [21], in which they indicate the algorithms that are being developed based on knowledge. Hence, using data mining and logical reasoning techniques, the tool will be capable of making recommendations for the use of certain wastes as raw materials in other processes. These recommendations will help the industry by identifying opportunities in the waste markets, enabling activity that could lead to the development of an active waste exchange network.

Bearing in mind that confidentiality is a key challenge in the implementation of industrial symbiosis, the input/output data of various databases will be exploited as the knowledge base of the SHAREBOX tool, the objective of which is to seek new synergies.

This waste symbiosis procedure will be replicated for other wastes, such as capacity, logistics, water and energy.

This tool will be tested in the "La Mina" industrial estate in Nules, in the Castellón ceramic cluster and in other industrial estates in the chemical industry throughout Europe (CCB-Chemie Cluster Bayern and NEPIC-North East of England Process Industry Cluster).

6. CONCLUSIONS

Through the analysis of the ceramic tile manufacturing sector in the province of Castellón, the industrial symbiosis processes currently existing in the sector have been identified, both between the sector's own companies and those of other sectors.

In addition, by gathering information possible new synergies were established. The existing potential is high, especially in synergies of substitution and of genesis, synergies of mutuality being those that could be carried out the most simply.

The SynerGie® program was used as a starting point for the establishment of synergies within three European industrial estates. In the case of Spain, specifically in Nules, companies from the ceramic sector were included along with companies from other industrial sectors close to the ceramic cluster.

The SHAREBOX tool, which is being developed within the Project framework, will allow the establishment of new synergies and flexible and automated management of those already implemented, using techniques based on knowledge such as: "data mining" and logical reasoning.

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8. REFERENCES

[1] COM (2015) 614 final. European Commission (EC), 2015. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy 2015.

[2] COM (2017) 33 final. European Commission (EC), 2017. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of the Circular Economy Action Plan 2017.

[3] CHERTOW, M.R. "Uncovering" Industrial Symbiosis. *Journal of Industrial Ecology,* 11(1), 11-30, 2007.

[4] RUIZ, M.C.; DIEZ, A.; ROMERO, E. Desarrollo de proyectos de simbiosis industrial en una región del norte de España.*XVI International Congress of Project Engineering*. Valencia 11-13 July 2012.

[5] Economía Circular en el País Vasco. Proyectos de demonstración para la reutilización de materiales. Ihobe. *Sociedad Pública de Gestión Ambiental*, 2014.

[6] https://www.manresa.cat/web/article/5977-projecte-simbiosi-industrial. Accessed:26/10/2016.

[7] BOU, E.; VICENT, M.; GOMAR, S.; CELADES, I. La simbiosis industrial en el sector de fabricación de baldosas cerámicas. Estado actual y posibles nuevas sinergias. *CONAMA 2016.XIII Congreso Nacional de Medio Ambiente.* Madrid 28 November - 1 December 2016.

[8] GARCÍA-TEN, J.; MALLOL, G.; BOU, E.; SILVA, G.; FERNÁNDEZ, J.; MOLINA, A.; ROMERA, J. Recycling marble working wastes in manufacturing ceramic products. Part I Waste characterization. *Cfi Ber.DKG*, 80(9), 84-90, 2003.

[9] GARCÍA-TEN, J.; MALLOL, G.; BOU, E.; SILVA, G.; FERNÁNDEZ, J.; MOLINA, A.; ROMERA, J. Recycling marble working wastes in manufacturing ceramic products. Part II Ceramic wall tile manufacture. *Cfi Ber.DKG*, 80(10), 30-32, 2003.

[10] BOU, E.; QUEREDA, M.F.; LEVER, D.; BOCCACCINI, A.; CHEESEMAN, CH. Production of pulverised fuel ash tiles using conventional ceramic production processes. *Adv. Appl. Ceram.*, 108(1), 44-49, 2009.

[11] GUZMÁN, A.A.; GORDILLO, S.M.; DELVASTO, A.S.; QUEREDA, M.F.; SÁNCHEZ, E. Optimization of the technological properties of porcelain tile bodies containing rice straw ash using the design of experiments methodology. *Ceramics International*, 42(14), 15383–15396, 2016.

[12] http://www.foundrytile.eu/. Accessed:29/09/2017.

[13] QUEREDA, M.F.; MOREDA, C., CLARENS, F.; MESAS, M. LIFE FOUNDRYTILE: Valorización de arenas y finos de fundición férrea en la producción de baldosas cerámicas. *QUALICER 2018.XV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico.* Castellón 12-13 February 2018.

[14] HAJJAJI, W., COSTA, G., ZANELLI, C., RIBEIRO, M.J., SEABRA, M.P., DONDI, M., LABRINCHA, JA. An overview of using solid wastes for pigment industry. *Journal of the European Ceramic Society*, 32(4), 753-764, 2012.

[15] BOU, E.; CELADES, I.; GOMAR, S.; GARCÍA-TEN, F.J. Análisis de la posibilidad de valorizar el residuo generado en la depuración de contaminantes ácidos emitidos en la industria cerámica. *Técnica Cerámica*, 431, 256-261, 2016.

[16] DEBUENO, P.; TOMÁS, A.E.; REIG, L.; PITARCH, A.; PALENCIA, J.J. Una alternativa sostenible para los residuos procedentes de baldosas cerámicas. *QUALICER 2016.XIV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico.* Castellón 8-9 February 2016.

[17] http://lifeceram.eu/. Accessed:29/09/2017.

[18] QUEREDA, M.F.; GARCÍA-TEN, F.J.; ROS, T.; GIL, C.; CHUMILLAS, D.; ZAERA, V.; SEGURA, M.C. LIFECERAM. Residuo cero en la fabricación de baldosas cerámicas. *QUALICER 2016.XIV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico.* Castellón 8-9 February 2016.

[19] http://www.lifecersuds.eu/. Accessed:29/09/2017.

[20] http://www.international-synergies.com/software/.Accessed: 28/09/2017.

[21] CAPELLEVEEN, G.; AMRITA, C.; MURAT, D.; ZIJMA, H. The influence of knowledge in the design of a recommender system to facilitate industrial symbiosis markets. *Environmental Modelling and Software Journal*, (paper submitted to the journal in March 2017).