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Environmental and economic assessment of brick production

Case study: Cerâmica de Pegões, SA

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1. Introduction

Along with the world population growth through mankind, the construction volume grew as well in order to satisfy the development necessities of that same population (AEA, 2007).

Worldwide construction is responsible for consuming 10% of economic funds (Roodman and Lenssen, 1995). It is kwon that it represents 9,7% of European Gross Domestic Product and 7,9% of the Portuguese GDP. Construction employs around 7% of labour (OCDE, 2003). It is estimated that 40% of global waste that is generated comes from construction and demolition (Koroneos and Dompros, 2007).

Clay bricks are the basic ceramic products most applied in Portugal when constructing buildings. The production of bricks is a traditional sector that contributes significantly to the national economy (Almeida *et al*, 2010). The life cycle of clay bricks could be long, around 80 years, owing to the great durability of ceramic construction products, and their potential to be recycled.

The consumption, waste and other consequences of the activity of construction result in a number of environmental impacts that it is important to study and understand. During all the phases that comprise the life cycle of a product there are impacts, from the extraction of raw materials, to transport, processing in plant, use and end disposal. The necessity of understanding the impacts throughout the life cycle appears increasingly as a way to identify and quantify the environmental critical points and support the development of less noxious solutions.

Life Cycle Analysis (LCA) is a methodology to assess the environmental pressure of process and products during all stages of their life cycle, from cradle to grave (Ortiz, 2008). Today LCA is normalized by a number of ISO 14000 standards, and covers the whole life cycle of a product, process or activity, including the actions of raw materials extraction, raw material processing, transformation in plant, transport, distribution, use, re-use, maintenance, recycling and final destiny.

To understand the environmental impacts of a traditional brick a case study was selected, the ceramic brick produced by the company Cerâmica de Pegões SA. the life cycle from the process of mining, including the mining facility, transport, production and packaging (cradle to gate) was taken into account. During the year of 2006, the production line suffered a modification regarding the fuel used in the plants furnace. Today the fuel used is biomass, collected from the remains of other industries, instead of thick fuel oil.

In this dissertation the LCA methodology is applied to study the environmental impacts associated to two brick production procedures through modelling all the processes in the software SimaPro and using the database Ecoinvent v2.0. At the same time the economical dimension was also evaluated, scaling the costs of both solutions that allow comparing the environmental and economic changes.

2. Case study

Cerâmica de Pegões SA production unit is located in Pegões, Montijo, in Portugal, it occupies an area of 31.873 square meters. In 2008 it manufactured 71.902 tons of clay bricks (around 17.500.00 units).

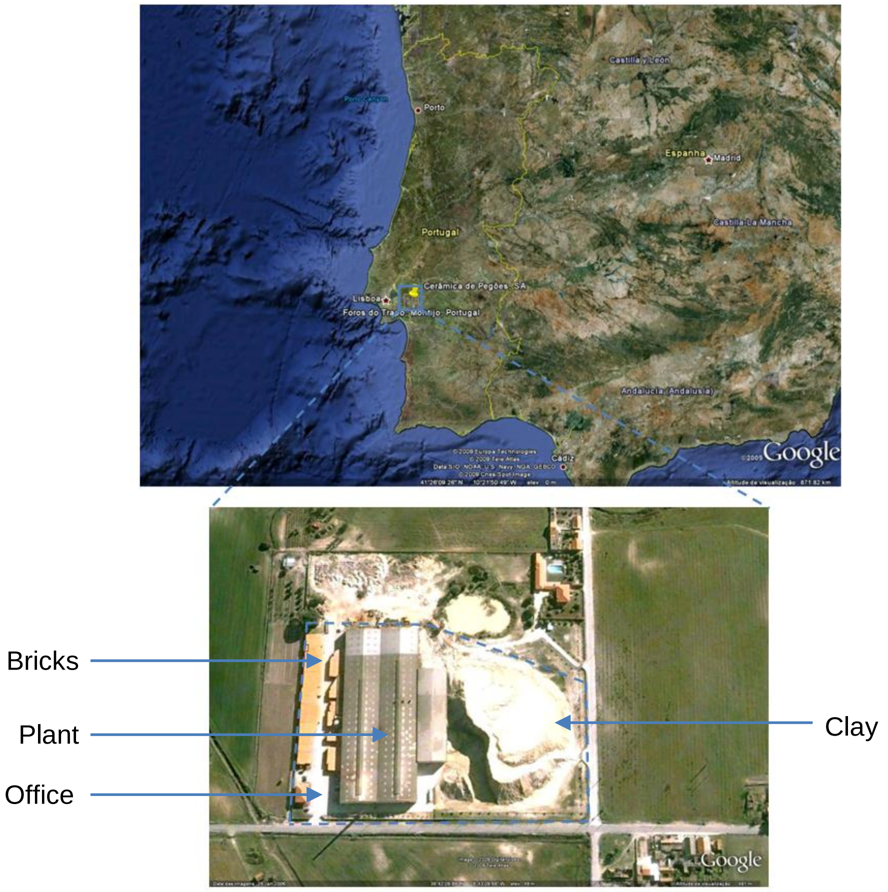

Figure 1 – Factory of Cerâmica de Pegões, SA

Cerâmica de Pegões SA dedicates its production exclusively to 30 x 20 x 11 cm clay bricks with a manufacturing process comparable to the average Portuguese reality. The company also owns several clay mines where all the clay required to satisfy the demand comes from. Clay is the central and most important raw material of this industry.

Extraction of clay occurs in quarries characterized for being an opencast mine located at no more than twelve kilometres from the plant. The excavation is done by heavy machinery that removes the clay which is transported by trucks, travelling no more than 12 km, to the plant where it is stored in a big pile. The clay starts by being separated from the waste and then water is added, if needed, so that a perfect humidity content is reached. Then, the mixture is left to rest in order to become homogeneous.

The mixture of clay is then submitted to moulding through extrusion in a vacuum chamber, and cut to required dimensions. After this stage the fresh bricks have to be left to dry in a semi-continuous drying chamber. The heat is recuperated from the main furnace and provided by a GPL heat generator when needed.

Dry bricks are then unloaded from the drying chamber and placed on kiln wagons that cross the furnace tunnel heated at around 900 ºC. The firing of the bricks is one of the crucial processes and occurs continuously and each wagon takes 18 hours to complete the cycle.

Finally the bricks are unloaded from the wagons, packed, palletised and taken to the shipping area as a final product.

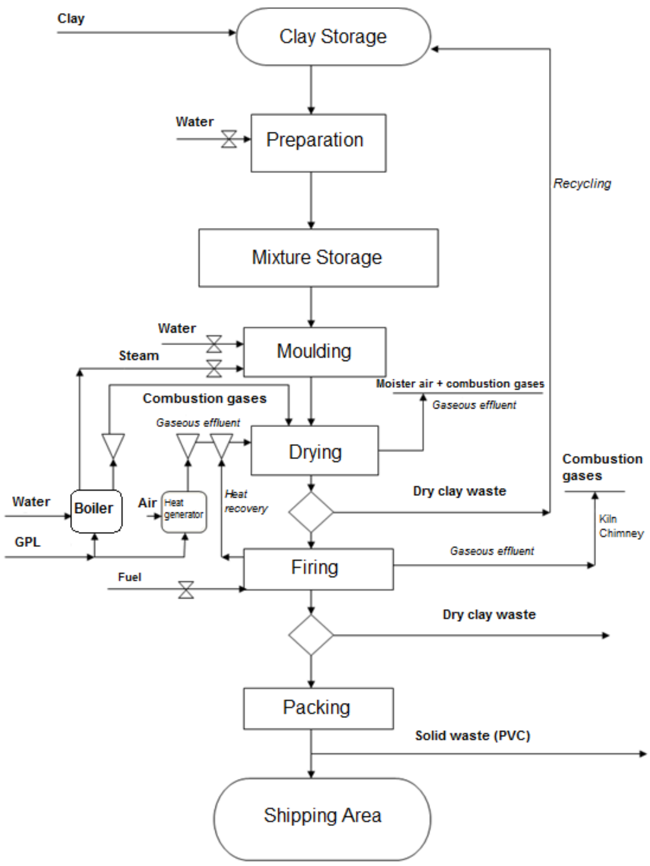

Figure 2 – Process flow of Cerâmica de Pegões, SA

3. LCA methodology and results

3.1 Objective and scope definition

The aim of this project was to identify, assess and compare the environmental impacts associated to raw-material extraction and plant production (cradle to gate) of a ceramic brick produced by two distinct processes by the company Cerâmica de Pegões SA.

The impacts were assessed by the application of the adopted method, Eco-Indicator 99, and two additional ones, Impact 2002+ and Ecopoints 97, in order to compare the global results, although the impact categories and the units that the scores are presented differ. It was also established the confrontation with a modelled brick that exists on the Ecoinvent 2.0 database to understand if the results reached make sense.

3.2 Functional unit and boundaries

The functional unit defined was one brick with 30 x 20 x 11 cm and 4,1 kg.

The phases of the brick life cycle that were subject of study where the processes of extraction, transport of clay to plant, transport of fuel to plant, production and packing (cradle to gate).

3.3 Model, its assumptions and inputs

Due the limitation of time and resources it was impracticable to assess profoundly every aspect related to the process on study. Only the inputs directly applied in the production process were taken into account. All the other impacts related to logistic operations, use and waste management at the end of life cycle were not under the scope. The activities regarding the factory construction, maintenance and workmanship activities were not considered.

In order to assess the impacts, the approach was to build two representative models of the life cycle consider using the software Simapro and database Ecoinvent 2.0. All the system inputs and the characteristics of every machine and way of transportation were analysed. The model was built despite the limitations imposed by the database and the most similar processes present in the database were to represent the real ones.

Table 1 has the information relative to the consumption of kilns fuel in 2005 (around 14.100.000bricks), the last year it was used 100% of thick fuel oil.

Table 1 – 2005 fuel inputs of Cerâmica de Pegões, SA

	Total	**Per brick**
Thick fuel oil	1.568.128 kg	0,1110 kg

All the other inputs, including the consumption of biomass, are presented on table 2 and are related the year 2008 (around 17.500.000 bricks).

Table 2- 2008 inputs of Cerâmica de Pegões, SA

	Total	Per brick
Electricity	2.301.190 kWh	0,131 kWh
GPL	50.893 kg	0,0029 kg
Biomass	6.723.640 kg	0,3834 kg
Water	5.557 m^3	0,000317 m^3
Clay	86.282 ton	0,00492 ton
Diesel	45.629 L	0,002602 L
Polypropylene strap	16.974 kg	0,000967 kg
Palet	81442 units	0,004644 units

Table 2 represents the data that is relevant to the life cycle inventory.*

3.4 Results and interpretation

After applying the Eco-indicator 99 method the results shown on figure 3 were obtained and the environmental score between the two processes that the study wishes to focus on are compared.

The differences between the two processes are evident in all characterization factors suggested by Eco-indicator 99. The brick produced by the process that uses biomass to forage the kiln (Biomass Brick) is less environmentally harmful than the one that uses thick fuel oil (Thick Fuel Oil Brick).

Considering not only that thick fuel oil is a non-renewal source of energy that when burned emits a large quantity of greenhouse gases but also that it has to be refined from crude understandable the huge difference in the resources category. The processes of thick fuel oil production plus the operation of the kiln represent 56,60% of Thick Fuel Oil Brick global impacts.

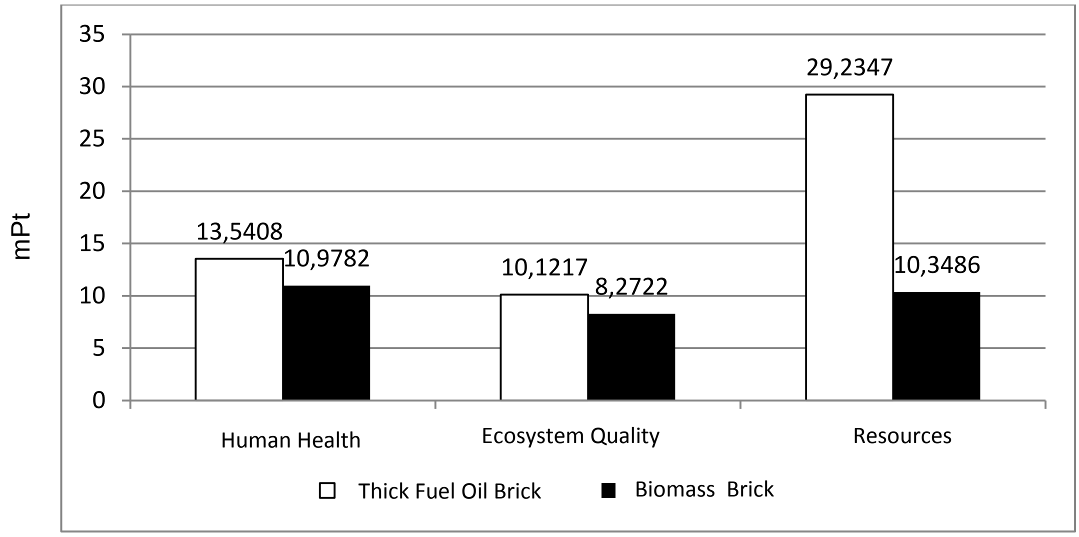

Figure 3 – Impacts of Biomass Brick and Thick Fuel Oil Brick, in mPt, Eco-indicator 99

Due the impossibility to compare directly the results obtained by the three methods applied (because the different units each presents the data), on table 3 is shown the total impact of both Thick Fuel Oil Brick and Biomass Brick. The differences between booth in analysis (clay extraction and production on plant) and between the brick that the database presents, are as well evidenced.

Table 3- Global results from the process through the three methods adopted

	Clay Extraction	**Thick Fuel Oil Brick**	**Biomass Brick**	**Ecoinvent Brick**
Eco-indicator 99 (mPt)	5,27	52,9	29,6	39,22
Impact 2002+ (μPt)	21,42	236,78	150,6	221,02
Ecopoints 97 (Pt)	74,63	705,23	422,22	634,71

Regardless the method adopted to study the impacts from the processes focused, Biomass Brick is the less harmful to the environment and Clay Extraction registers a much lower impact compared to the other production life cycle stage. For a brick that was produced by the Thick Fuel Oil process, Clay Extraction represented an average of 8,99% of total impacts and 14,30% when biomass was used.

The order of magnitude between the Ecoinvent Brick and the other two processes is comparable which indicate that the model built is reasonable. The Ecoinvent Brick uses GPL as kiln fuel, less noxious to the environment then thick fuel oil but still far from the biomass.

4. Economic dimension

The comparison between the costs registered before and after the transformation regarding the price of thick fuel oil, which is estimated to be lower than in 2008 by the market fluctuation recorded until 2007. The cost to the two productions is shown in table 4.

Table 4- Costs associated to the volume of production (around 17.500.000 units) in 2008

	Costs ($€/ton$)	Total consumption (ton)	Total cost ($€$)	Cost per unit ($€/unid$)
Thick Fuel Oil Brick	267,98	1.947	521.859	0,0298
Biomass Brick	32,09	6.723	215.761	0,0123

The total costs regarding the kiln fuel dropped from 521.859,696 € to 215.761,607 € and from 0,0298 € to 0,0123 € per unit of brick produced. Economically the shift brought an immediate improvement with a negligible investment.

5. Discussion

The assumptions set at the beginning proved to be balanced and reasonable, as the results that were obtained with the models that were built based on data collected in the field (Thick Fuel Oil Brick and Biomass Brick) are of the same order of magnitude of those obtained with the existing model by setting the simulator (Ecoivent Brick). However to obtain results which reflect the full benefit in terms of the impact a complete analysis would be necessary to make a detailed modeling of all processes present in the factory.

It was demonstrated that the kiln and all the process associated with it are the cause of the greater impact on the environment throughout the life cycle of the brick in question. So it makes sense that it is in the furnace that the strongest effort of improvement in regard to environmental performance is focused.

In order to proceed with the study, it is suggested to extend the work to the complete life cycle of clay bricks, from the extraction of raw materials to the possibility of recycling (cradle to cradle).

6. Conclusion

This work based in a LCA study analyses the impact assessment associated to the production of clay bricks from cradle to gate and compares two distinct solutions of manufacturing processes.

The great majority of the impacts are related to the firing of the bricks (58,6% in the thick fuel oil case and 30,4% in the biomass case), and its effects are mostly associated to air emissions. It was proven that changing the fuel on the kiln results on major differences in terms of environmental impacts. In summary, a reduction of 44,03% was reached on the environmental impacts and 58,66% on costs.

Thus it is possible through this case study to demonstrate a solution that improves a company, both environmentally and economically, showing a relation that can contribute to the search for sustainability.

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