THE OPPORTUNITY OF COGENERATION IN THE CERAMIC INDUSTRY IN BRAZIL – CASE STUDY OF CLAY DRYING BY A DRY ROUTE PROCESS FOR CERAMIC TILES

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ABSTRACT

In this work two alternatives (turbo and motor generator) using natural gas were considered as an application of Cogeneration Heat Power (CHP) scheme comparing with a conventional air heater in an artificial drying process for raw material in a dry route process for ceramic tiles.

Considering the drying process and its influence in the raw material, the studies and tests in laboratories with clay samples were focused to investigate the appropriate temperature of dry gases and the type of drier in order to maintain the best clay properties after the drying process.

Considering a few applications of CHP in a ceramic industrial sector in Brazil, the study has demonstrated the viability of cogeneration opportunities as an efficient way to use natural gas to complement the hydroelectricity to attend the rising electrical demand in the country in opposition to central power plants.

Both aspects entail an innovative view of the industries in the most important ceramic tiles cluster in the Americas which reaches 300 million squares meters a year.

1. INTRODUCTION

1.1. The energy scenario in Brazil.

In Brazil more than 80% of the country's installed capacity of electric energy is generated using hydropower. In the last years the process of increasing generating capacity while reducing the country's dependence on hydropower began with the introduction of on-line auctions for new capacities to be delivered in either three or five years, which rules out new hydropower projects.

A cogeneration heat and power technology (CHP) – producing electricity and heat at the same time - is one of the simplest ways to use primary fuel efficiently and reduce CO_2 emissions. As delivering heat over long distances is complex, cogeneration usually results in distributed power solutions; nonetheless, small plants distributed over a large area can also be operated as peak power providers, stabilizing the grid.

According to BERG and NOGUEIRA (1996) the CHP viability in Brazil has some variability, depending on the specific legislation and energy relative costs, representing some difficulties for its desirable expansion.

In the past there were some difficulties to guarantee the natural gas supply; however this situation is changing quickly, with the implementation of mechanisms to guarantee the natural gas safe supply to the industries based on an energy policy.

However, until now there are only few CHP applications in Brazil. The last CHP application in a ceramic industry is the natural gas turbine based installation (4.500 kWe ISO) at PAMESA. The industrial plant is located in the North Region in a Cabo de Santo Agostinho city close to the Recife metropolitan area. It is a conventional application of CHP scheme in Spray Dryer, and it exports part of the electric power to the grid.

2. THE CERAMIC INDUSTRIES IN BRAZIL

In spite of the 2008 international economic crisis, the Brazilian ceramic tile production reached 713 million sq. m. giving to the country the status of the second major world producer. Expectations for 2009 are to produce the same amount, with a growth forecast above 5% next year, due to an expansion of the domestic demand. The production process is divided in two types: dry and wet processes, according to the media of milling of raw material, dry and wet process.

The Santa Gertrudes ceramic manufacturing pole, located in the state of São Paulo (figure 1), southeastern Brazil, produces over 300 million square meters of tiles per year in around 40 manufacturing units.

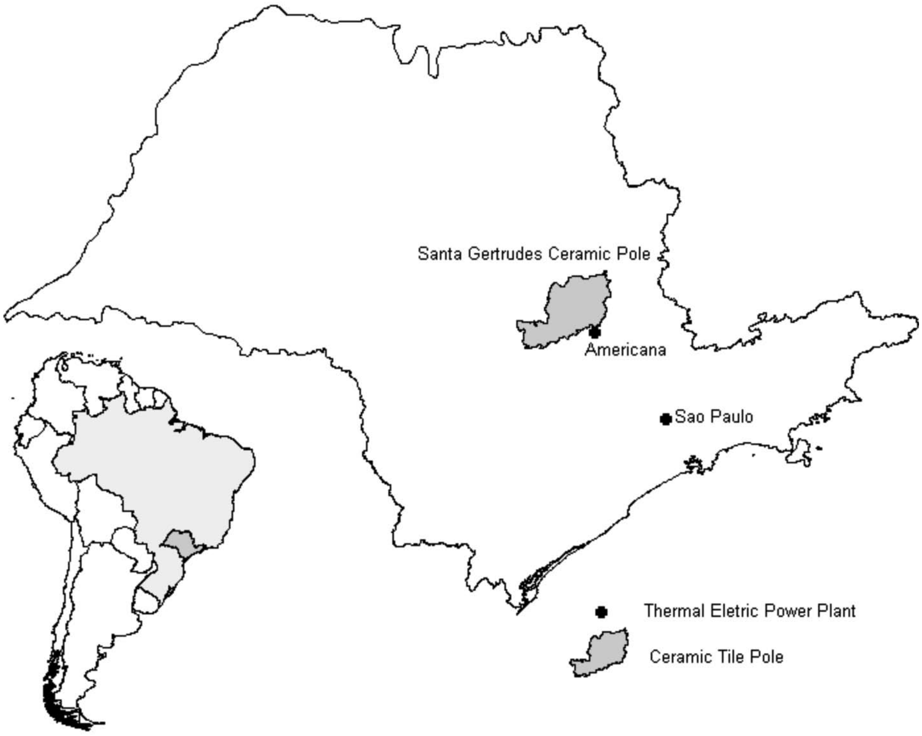

Figure 1. The Santa Gertrudes geographic location.

The main characteristics of the tiles produced in Santa Gertrudes are the dry process, the reddish color of the ceramic body, water absorption between 6 and 10% (BIIb type), and a glazed surface. The manufacturing through a dry process is facilitated by the single raw material (clay) used in the body's composition. This material comes from clayey rocks in the Paraná basin, a huge Phanerozoic intracratonic sedimentary basin covering 1,100,000 square kilometers in southern Brazil, and 100,000 square kilometers each in Uruguay, Paraguay and Argentina. In the region of the Santa Gertrudes pole, clayey rocks used as raw material in the manufacture of ceramic tile bodies are grouped in the Permian Corumbataí Formation (Pc). This is an up to 130-meter-thick layer of shallow reddish marine sediment containing claystone, shale, siltstone and fine sandstone. The main minerals in these clayey rocks are illite, with minor amounts of smectite and kaolinite, and quartz, feldspar, hematite and iron hydroxides. The main oxides present here and their approximate chemical composition are: SiO_2 (67%), Al_2O_3 (15%), Fe_2O_3 (5%), K_2O (3-4%), Na_2O (0.5%) and CaO (0.5%).

Mining is conducted by traditional open pit methods, involving the usual stages of clearing the vegetation (sugar cane field) and stripping, followed by blasting or scraping (depending on the rock strength) using single or multi benches. Ore, in the form of cobbles and pebbles, is loaded onto trucks and transported as run-off-mine to outdoor ageing stockpiles or to a primary crusher and then goes to outdoor terraces for blending, grain size reduction, homogenization and drying by sun light.

However, the outdoor works for drying generates a lot of powder which is carried out to the atmosphere and drainage system, decreasing air and water quality. To reduce this pollution the local environmental agency has set up restrictions to this drying method.

Looking for technical and environmental alternatives, the study carried out and presented here deals with a CHP application for drying clay in an indoor environment instead of natural outdoor one. This CHP application is not usual, and the result is still on analysis.

The main purposes of this study were:

- Investigate in laboratory the temperature limits for artificial drying process in order to save clay properties, mainly related to plasticity and green strength;
- Based on laboratory works, design a conventional drying and conjugated dryer and CHP alternatives, for one typical ceramic plant considering the local aspects and related energy costs;
- Estimate costs involved in this new process of drying clay in relation to present method and its effects on environmental impacts; and,
- Provide a basis for government evaluation, such as advantage and disadvantages for onsite CHP electric power generating in comparison with non-onsite generation by using natural gas.

3. NATURAL DRYING ENERGY CONSUMPTION AND EMISSIONS

The present process for drying clay in Santa Gertrudes is shown in a simplified flow sheet in figure 2. Despite the use of sun as the main energy source, a lot of diesel oil is still used for transportation and works in the open terraces. The intensive raw material movements in these operations imply in high costs, air and water pollution around the operating sites.

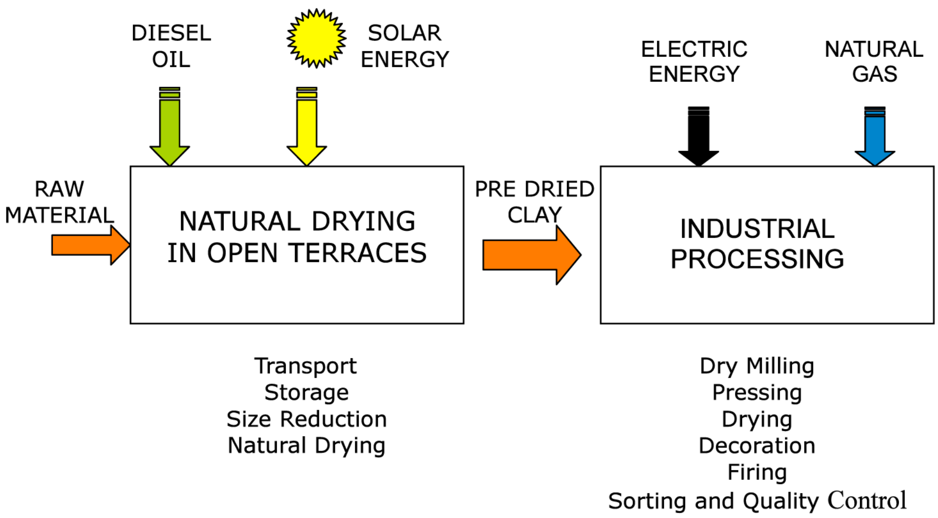

Figure 2. Simplified flow sheet of present situation.

4. THE FORCED DRYING ALTERNATIVES

In order to try to replace the natural drying some industries have adopted a conventional drying system. In two cases analyzed, rotary dryers types were used where the drying agent is introduced at a temperature ranging from 300 ºC to 400 ºC. In both cases some changes were noticed in the clay properties. So, the adopted solution by producers was to apply a limit of 50% of this artificial dried clay in the total clay composition.

In the present study many tests were carried out in the laboratory to investigate the behavior of the clay under different drying temperatures so as to define maximum temperature without significant losses of plasticity. As an example, figure 3 shows a decrease of strength of the dryed ceramic body at higher temperatures, of two samples of clays in the Santa Gertrudes region.

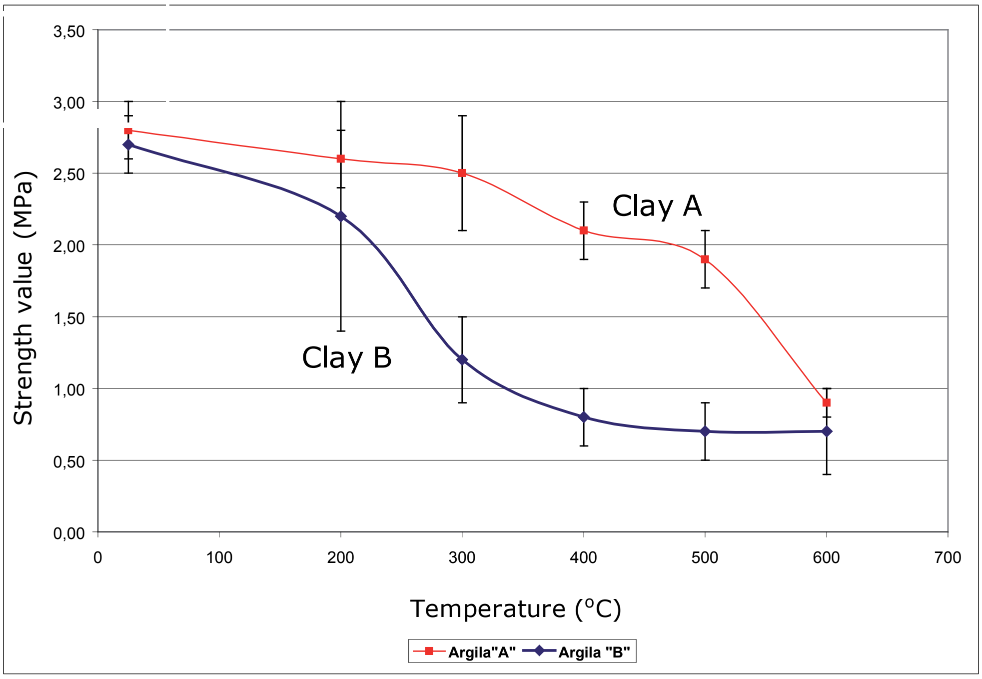

Figure 3. Strength as a function of drying air temperature for different clays.

The strength value was one of the most important parameters considered to evaluate the best drying temperature. It was established temperature near below 250 °C in order to provide some efficacy to the process and to preserve the peculiar clay characteristics in the dry pressing step. Taking into account these results, the drying process must be done at low temperature and short residence time, where the application of chamber type dryer "rapid dryer" (figure 4) should provide better performance than the conventional rotary one.

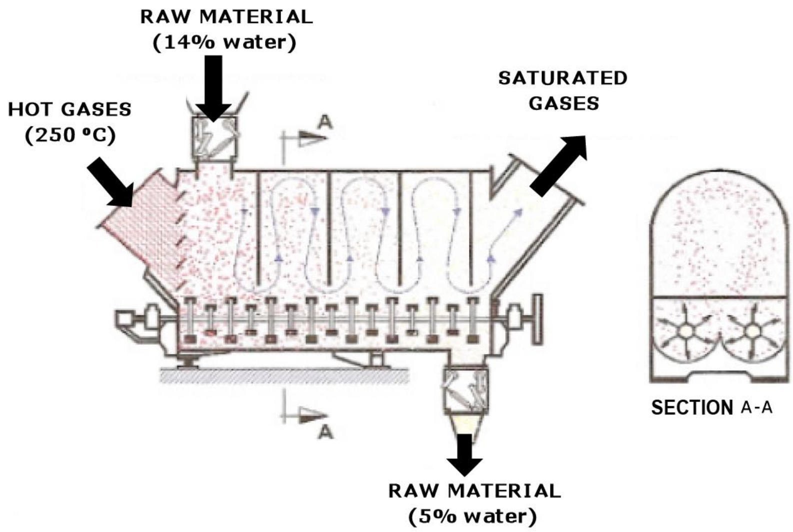

Figure 4. The "Rapid Dryer".

In this study, two "rapid dryer" units were used for the typical installation as an example, for a production of 1.65 million square meters tiles a month.

5. THE CONVENTIONAL DRYING ARRANGEMENTS

To study an application for a typical case, the following parameters had been considered to specify the processing capacity to the pre-drying plant: 59 tile square meter/t clay; 550,000 sq. meters/month; dry-clay production: 31.25 t/h (nominal capacity: 40 t/h).

In spite of the different types of clay in the region, the following values were adopted to make the calculation possible: water content in a natural clay: 15%; water in a dried clay: 5%, that results in 4000 kg/h of flow rate of evaporated water. Assuming a 81% thermodynamic drying efficiency and a specific energy consumption: 1000 to 1200 Kcal/kg of evaporated water, which is typical for dryers at 250 ºC drying air temperature,it results in the maximum thermal capacity of 4.8 Gcal/h (5.58 MW), and a flow rate of 63,000 kg/h of drying gases.

As a reference for comparisons, a conventional drying arrangement was considered using a furnace (combustion chamber) to produce hot gases by natural gas direct firing as illustrated in figure 5. In this case the nominal furnace capacity is 7.63 MW.

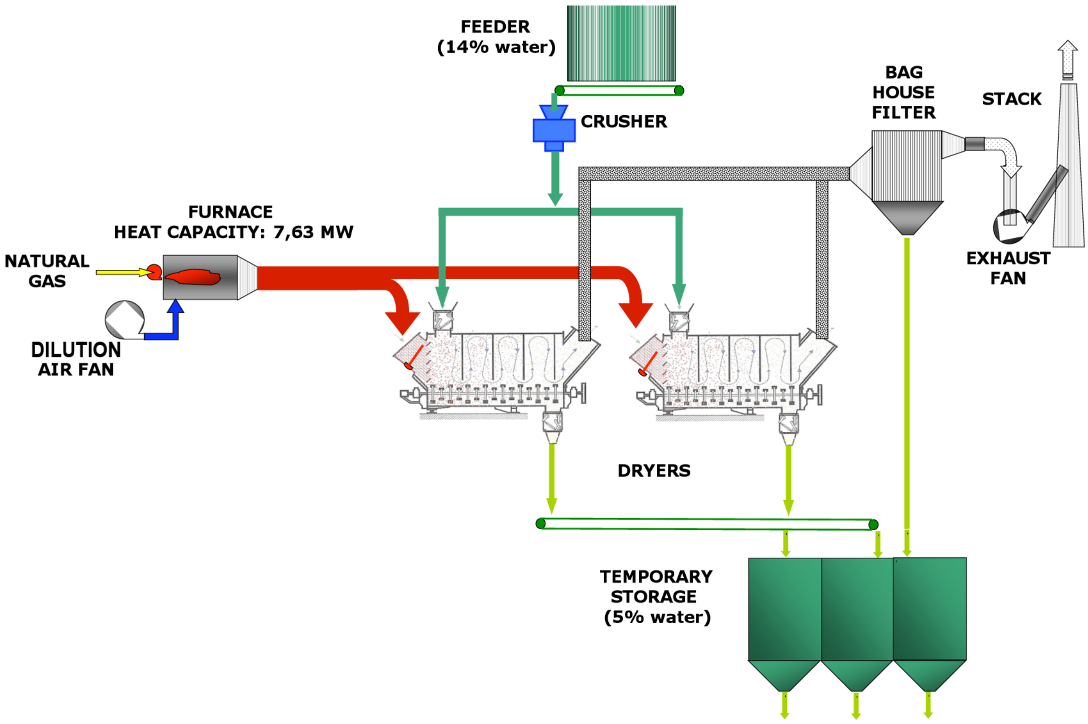

Figure 5. The conventional arrangement to forced drying.

6. THE SCHEMES FOR CHP APPLICATION

In the flow sheet in figure 6 the CHP is considered to supply the thermal and electric power demands for drying the clay in forced way in closed environments, part of the electric power will be exported to the industrial facilities, in some cases located near, or will be sent to a grid. Depending on the option, engines or turbines, some exceeding electric power should be exported to external grid.

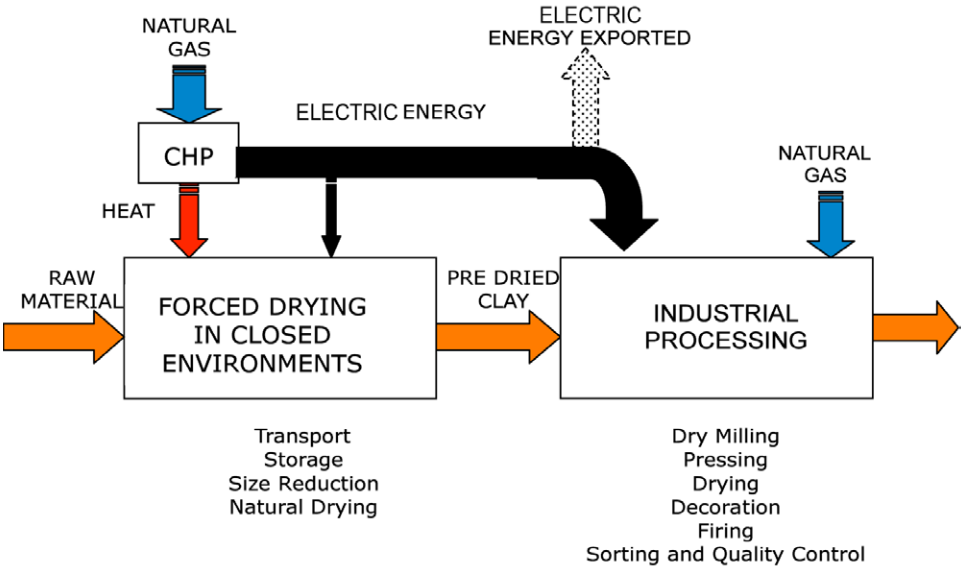

Figure 6. Simplified flow sheet of the CHP alternative.

In figure 7 the arrangement considers three reciprocating engines with nominal power (each 2 MWe) enough to supply hot gases to two dryers. The exhausted gases must be diluted with fresh air to control the drying temperature at 250 ºC at the dryer inlet.

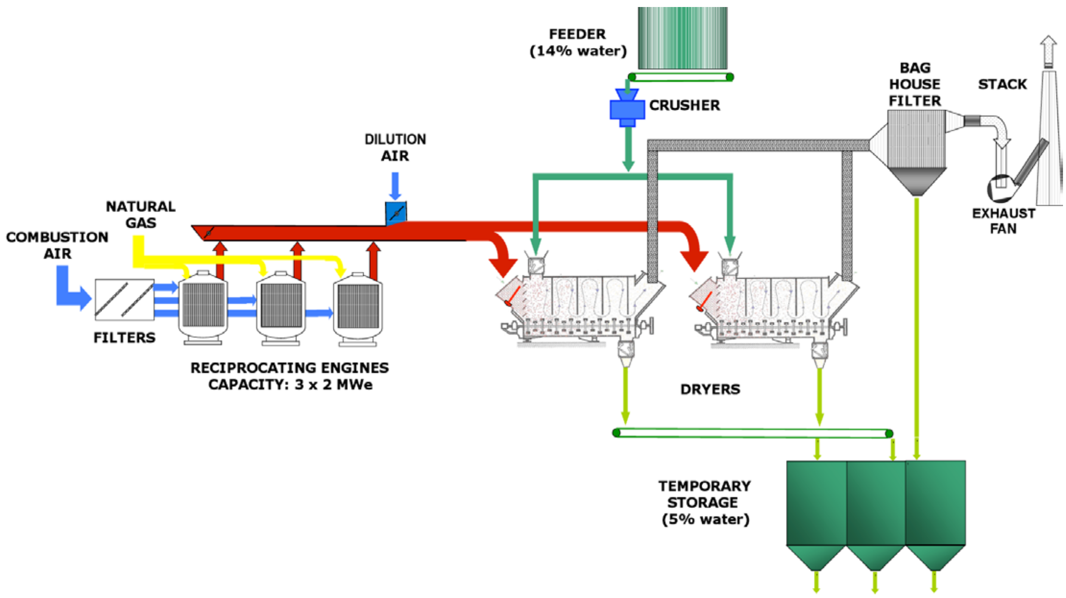

Figure 7. The CHP scheme using engines.

In figure 8 the arrangement considers one set of turbo generator (air compressor plus turbine) with a 3 MWe as a nominal power, enough to supply hot gases to two dryers. The exhausted gases must be also diluted with fresh air to control the specified drying temperature.

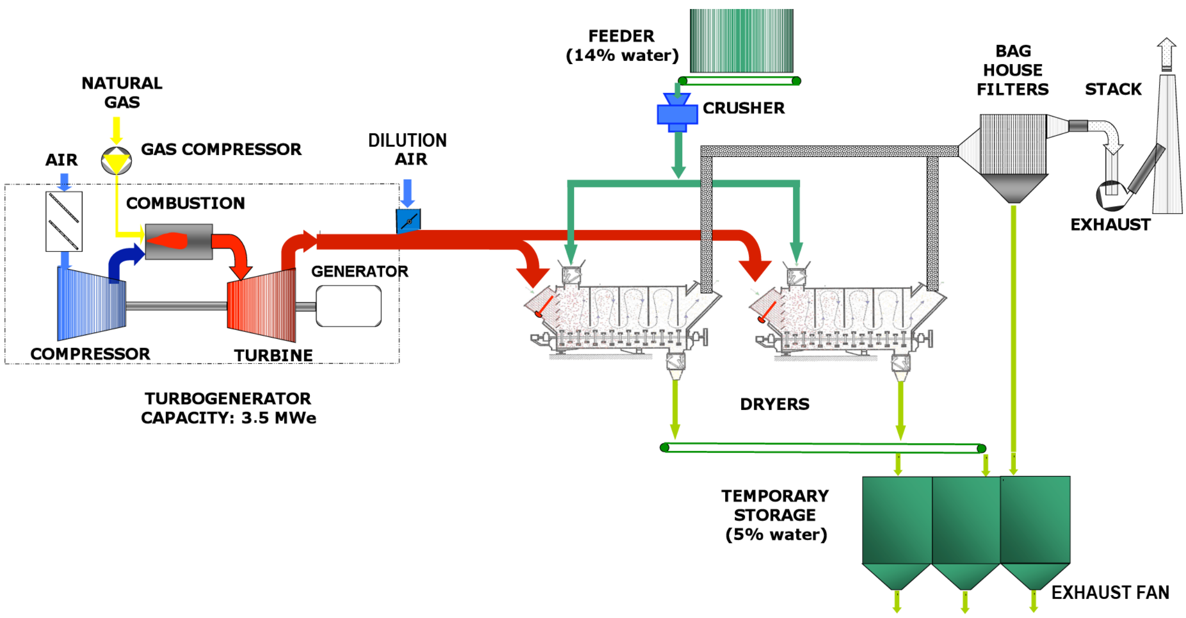

Figure 8 – The CHP scheme using turbo generator.

7. COMPARATIVE ARRENGEMENTS ANALYSIS

The following analysis considers all of the three alternatives taking into account the heat and electric power ratio and the economic parameters for the investments. To obtain the same thermal power, the installed power must be quite different as a result from the ratio heat/work differences for both CHP alternatives. These figures are estimated to a typical plant for 1,650,000 sq. m a month.

		FURNACE	CHP	
			ENGINE	TURBINE
TOTAL	KW	5,140	10,495	7,915
THERMAL POWER	KW	5,140	5,140	5,140
	%	100	49.0	64.9
ELECTRIC POWER	KW	-	4,078	2,142
	%	-	38.8	27.0
HEAT / WORK	-	-	1.26	2.40

Table 1. Heat and electric power ratio.

		NATURAL DRYIING	FORCED DRYING		
			FURNACE	CHP	
				ENGINE	TURBINE
Specific NG. consump	Nm^3/m^2	1.00	1.19	1.37	1.28
Total Power release	KW	-	5,396	10,495	7,915
Thermal power	KW	-	5.140	5,140	5,140
Electric power	KW	-	-	4,078	2,142
Electric demand	KW	2,842	3,197	-	1,054
Economy	US$/year	-	346,542	3,600,770	1,233,025
Investment	US$	-	1,975,512	4,962,653	4,564,780
Internal Rate Return	%	-	15.53	72.54	26.19

Production: 1,650,000 m^2/month
Natural Gas =0.4098 US$/$Nm^3$ (normal); 0.3774 US$/$Nm^3$ (only for cogeneration); electricity= 5.14 US$/KW; 0.1249 US$/KWh.

Table 2. Economic analysis.

8. THE CHP IMPACTS ON DIFFERENT SCENARIOS

Nowadays there are some limitations in the electric distribution systems near Santa Gertrudes pole. The expectation is that the economic growth will very quickly increase the internal tile market, pressuring the natural gas demand. However, there are some expectations of a substantial increase of the gas production near the sea coast. Taking into account the necessity to complement hydraulic based generation to attend the electric energy demand with natural gas, it is imperative to consider the CHP applications.

Based only on the figures of Santa Gertrude's pole, considering an increase of production estimated in 378 million sq. m. tiles a year, some values of natural gas and electric energy consumption are presented on tables 3 and 4 considering different situations: present (natural drying), furnace (conventional forced drying) and both CHP´s alternatives (engine and turbine).

With an engine alternative the negative value represents a possibility to export to the external electric grid of São Paulo state. The turbine options represent a reduction of 63% in an electric energy demand from the grid.

		NATURAL DRYING	FORCED DRYING		
			FURNACE	CHP	
				ENGINES	TURBINE
Annual production	10^6 m^2	378	378	378	378
Specific consumption	Nm^3/m^2	1.00	1.19	1.37	1.28
Natural Gas consumption	Nm^3/day	1,0035,616	1,233,589	1,420,640	1,325,984
Electric demand from grid	MW	54.25	61.03	-17.51 (*1)	20.12

*(*1) Electric Power exported to grid.*
Table 3. Energy forecast for Santa Gertrudes pole.

Table 4 presents the total consumption of natural gas in São Paulo State considering three alternatives to attend the electric energy demand from industries in the Santa Gertrudes pole. To estimate the natural gas consumption in central power plants three alternatives are considered: the electric power is generated in a thermo power plant located in Americana very close to the pole (see figure 1), fueled by heavy fuel oil (efficiency 21%). The second situation considers an upgrade in the same power plant fueled by natural gas (efficiency = 35%). The third alternative considered is the electric demand supplied by a central thermal power located in São Paulo, natural gas fueled (efficiency = 55%), 180 km away from the Santa Gertrudes pole (see figure 1).

			NATURAL DRYING	FORCED DRYING		
				FURNACE	CHP	
					ENGINES	TURBINE
Electric demand from grid		MW	54.25	61,.03	-17.51	20.12
AMERICANA (fuel oil) (*1)	Thermal efficiency	%	21			
	Fuel consumption	Nm^3/day	1,605,664	1,874,834	1,236,671	1,537,406
AMERICANA (GN)	Thermal efficiency	%	35	35	35	35
	Fuel consumption	Nm^3/day	1,375,947	1,616,426	1,310,306	1,452,207
S. PAULO	Thermal efficiency	%	55	55	55	55
	Fuel consumption	Nm^3/day	1,252,190	1,477,212	1,350,746	1,406,308

*(*1) Energetic equivalent consumption oil/NG;*
Table 4. Total natural gas consumptions.

Considering the highest efficiency for central generation, the use of local electric generation by engines with theCHP alternative represents an economy of 126,466 Nm^3/day (8.6%) comparing with a conventional furnace alternative.

8. CONCLUSIONS

The Santa Gertrudes ceramic pole, in Sao Paulo State, Brazil, produces over 300 million sq. m a year of floor and wall tiles, based on 100 % clay ceramic body. Clay is dried by using natural process under the sun, but it's bringing some environmental problems, due to emissions of extra fine particles to the atmosphere and water bodies, in addition to the equipment and fuel costs. This study evaluated some economic and technical parameters to introduce artificial drying methods, some of them as an innovative process to reduce the natural moisture of clays (around 15 wt%) to 5%, to get desirable conditions to be dry milled. This dry route for powder preparation is a typical and cheap solution for Santa Gertrudes tiles. Some important conclusions are:

- It's possible to replace the present natural drying system by using an artificial system, but some precaution should be taken, such as: the drying agent temperature should not exceed 250 °C and a short drying cyle is recommended;
- Several alternatives combining processes and equipment present technical and economic feasibility, but some additional advantage would be observed when CHP is used, mainly based on engine.

- With regard to the overall energy consumption, the generation of electric energy from a natural gas plant should have more advantages in local co-generation, such as this CHP for clay drying, than a centralized thermoelectric plant.

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