Integrated Renewable Energy Systems in a Brickyard

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1 Summary

Energy sources used in the clay brick making process are dominantly derived from fossil fuels. However, through innovative development it has been shown possible for these traditional sources to be successfully replaced by renewable alternatives reducing greenhouse gas emissions to almost zero. A further step in improving energy efficiency is cogeneration, CHP, a highly efficient means of generating heat and electric power at the same time from the same energy source. Displacing fuel combustion with heat that would normally be wasted in the process of power generation, it reaches efficaciousness that by far exceeds conventional generation. Cogeneration installations can use liquid renewable fuels such as vegetable oil, recycled frying oil and rendering fat. The environmental implications of cogeneration stem not just from its inherent efficiency, but also from its decentralized character.

2 The principle

The environmental impact of the brick production process is mostly due to the consumption of energy for drying & firing of the bricks.

Reduction of environmental impacts is certainly important today. Nevertheless, most probably such measures will not take place on a voluntary base if they generate additional expense hence increasing overall production costs. Today's stiff competition does not leave room for passing on additional environmental cost to the customer. Hence the solution must be, in order to be winning, cost neutral. That a sensible reduction of the environmental impact associated to a sensible reduction in production costs can be achieved is demonstrated hereto following.

The presented example is based on real world data. It is a two step solution: first fossil fuels for firing are substituted with suiteable renewable fuels. In a second step a CHP system is incorporated.

3 Energy use in a brickyard

The average direct thermal energy consumption of a structural clay brick production process is to be found ranging between 1.450 and 2.725 kJ/kg of fired brick. For the purpose of this paper energy data from the Gasser ISO 14,040 compliant life cycle analysis ([1]) are used. Data for this analysis are either site specific data or derived from commonly available data bases such as GABI 4([2]) or Boustead ([3]).

Today bricks are usually fired in a tunnel kiln in which fire remains stationary and bricks are moved on kiln cars through a tunnel divided into preheat, firing and cooling zones. To the production process energy content of the product, or grey energy, energy contents due to transport and production of raw materials must be added in order to obtain the overall environmental impact.

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[1] www.gasser-online.com
[2] http://www.gabi-software.com/
[3] http://www.boustead-consulting.co.uk/

Table 1: energy content values for selected construction materials

	Bulk density kg/m3	Total Energy content MJ/m^3
Brick fired with fossil fuels	700	2,801.68 ([4]) ([5])
Reinforced concrete	2,400	5,264.90
EPS	20	1,928.00
Rock Wool	80	1,399.40

All of this energy is traditionally generated using fossil fuels.

Should all the fuels used in the brickyard substituted with renewable fuels, the total energy content would be:

Table 2: energy content fossil fuel fired brick ./. renewable fuels fired brick

	Bulk density kg/m3	Total Energy content MJ/m3
Brick fired with fossil fuels	700	2,801.68
Brick fired with renewable fuels	700	1,051.40 ([6])

A brick fired with renewable fuels would feature the least energy content for a given volume of all building products available on the market today.

4 Energy flow in a brickyard

Roughly about 2/3 of the thermal energy are used to fire the bricks and 1/3 is used to dry the wet extruded bricks. These assumptions hold true for load bearing hollow bricks. For facing bricks or tiles the situation is different and not covered by this paper.

The heat energy flow in a brickyard is relatively straightforward:

Graph 1: heat energy flow in a brickyard

QuickTime™ e un
decompressore TIFF (LZW)
sono necessari per visualizzare quest'immagine.

5 Sustainability

[4] All brick data derived from Gasser 2004 LCA data, all other data GBC handbook http://www.gbc-ziegelhandbuch.org/ not available in print at the time of writing. The total energy content, including renewable resources and transports of raw and finished materials, is 4,002.40 MJ/t(Boustead data model). For the use phase the total energy content is 266.20 MJ/t (Boustead data model).

[5] The total energy content due to firing and drying of the brick is 2,500.40 MJ/kg as per Gasser 2004 LCA data.

[6] This figure does not take into account electric energy generated on – site by a CHP system running on renewable fuels. In this case the figure would be < 950 MJ/m^3

While no production process will ever be completely benign, the utilization of renewable resources in substitution for fossil or quarried resources can benefit the environment considerably. By buying green instead of conventional, consumers can reduce the environmental impact caused by their use of manufactured goods. Fuel substitution away from carbon intensive fuels to renewable and alternative fuels can ameliorate greenhouse gas emissions.

The emission data for the Gasser brickyard running on renewable fuels are among the lowest in the industry.

Table 3: emission data fossil fuel fired brick ./. renewable fuels fired brick

	Unit	Industry		Gasser 2004
		Min	Max	
Dust	mg/m^3	1	30	2.63
NO_x as NO_2		10	550	22.0
SO_x as SO_2		10	200	4.53
Fluoride as HF		1	120	0.28
Chloride as HCl		1	20	4.04
Total organic		50	250	Not measurable
Ethanol average	mg/kg brick	3,1		<0,01
Benzol	mg/m^3	1	65	
Methanol avera	mg/kg brick	5,7		
Phenol	mg/m^3	5	100	
Formaldehyde		1	20	
Aldehyde (S C1 – C4)		1	180	
Carbonmonoxide		<300	< 1.500	78.52

All emission data are normalized to 17% Oxygen as per Italian legislation.

If now not only fuel for the direct firing of the bricks but also for operations such as drying are used, the impact can be even greater. If a CHP system is used, the impact is paramount. The only negative impact on the environment would be from emissions due to transport and quarrying. Albeit even there the use of renewable fuels would be feasible (biogas or palm oil fired engines for example).

Table 4: avoided emissions due to the use of renewable fuels in tons per year

	t CO_2 / 8000 hours
Kiln	8.845,22
Dryer	4.422,61
Electricity	3.186,00
Total per year	16.453,83

6 Economics

For medium sized brickyard featuring a daily output of about 250 metric tons day, the energy figures would be, based on a lower calorific value of 32,000 kJ/Nm3 of natural gas, for a plant running on natural gas be:

Table 5: required natural gas

250 t/day x 1000 kg x 2,500.40 kJ/kg =

	day	h
Kiln kJ	416.733.333,33	17,363,888.89
Dryer kJ	208,366,666,667	8,681,944.44
Kiln kW	115,851,87	4,827.16
Dryer kW	57,925.93	2,413.58

Kiln Nm^3	11,263.06	469.29
Dryer Nm^3	5,613.53	234.65

At current prices in Italy for a Nm3 natural gas a kWh of thermal energy generated will have a cost of approximately 0,0345 €.

The same calculation assuming that the plant is fired with a renewable fuel such as palm oil featuring a lower calorific value of 37.000 kJ/kg would be:

Table 6: required renewable fuel (palm oil)

	day	h
Kiln kg	11,263.06	469.29
Dryer kg	5,631.53	234.65

At current prices in Italy for palm oil the cost per kWh of thermal energy produced would be approximately 25 % higher. Considering revenues from the sale of avoided CO_2 emissions and fossil energy savings, so called white certificates, rights, the cost would result lower! The use of renewable fuels in a brickyard can hence be of considerable effect on the environment, stakeholders perception of the operation itself and overall economies of the operation provided the right governmental subsidies are available.

7 Dimensioning a CHP system

Because it is impractical to transport heat over any distance, cogeneration equipment must be located physically close to its heat user. A number of environmentally positive consequences flow from this fact: Electric power tends to be generated closer to the consumer, reducing transmission losses, stray current, and the need for distribution equipment significantly. Cogeneration plants tend to be built smaller, and owned and operated by smaller and more localized companies than simple cycle power plants. As a general rule, they are also built closer to populated areas, which causes them to be held to much higher environmental standards. Cogeneration is at the heart of district heating and cooling systems. District heating combined with cogeneration fueled by renewable fuels has the potential to reduce human greenhouse gas emissions by more than any other technology except public transit.

Low temperature heat generated in a CHP system can be used to preheat combustion air for high speed burners, preheating and efficient burners resulting a 5 to 10% saving of total thermal energy requirement that is not considered in the calculation.

The principle behind cogeneration is simple: conventional power generation is, on average, about 35% efficient " the remaining energy potential is released as waste heat. Decentralized combined heat and power systems, CHP, reduce this loss by using the heat for industry, commerce and home heating/cooling. Transport land distribution losses, usually around 5-10%, from relatively remote power stations via the electricity grid are avoided. The overall efficiency of a renewable fuels fired CHP system can reach 90% or more. In addition, the electricity generated by the cogeneration plant is normally used locally, and then transmission and distribution losses will be negligible. Cogeneration with CHP systems therefore offer more than considerable energy savings when compared against the conventional supply of electricity and heat. Transporting electricity over long distances is easier and cheaper than transporting heat, the reason why CHP installations are usually sited as near as possible to the place where the heat is consumed and are built to a size to meet the heat demand. Surplus electricity can be sold to the grid.

Table 7: Thermal dimensioning of the CHP system

Requirement day kWh_t	57,925.93
Requirement hour kWh_t	2,423,.58
kWh_e CHP system required	2,172.22

a CHP system of about 2,200 kWh_t is required.

The electric energy required to run the brickyard is to be found between 60 and 110 kWh/t. Assuming an average value of 85 kWh/t the required electricity would:

250 t/day x 85 kWh/t = 21.250 kWh/day = 885 kW per hour of operation

Assuming a double shift opertion of the brickyard:

885 kW x 16 = 14.150 kWh/day

whereas production is

1.450 kW x 24 = 34.500 kWh/day

more than double what is needed. The not required electric energy, about 32.000 kWh/day, can be delivered to the grid for a profit.

Assuming that a CHP running on renewable fuels has a specific consumption of about 300 g kW_e:

Table 8: fuel consumtion CHP system

	day	h
Fuel consump-tion	15.788,87	657,87

8 Financial aspects

Considering the CHP system as a stand alone solution not supplemented by the subsitution of fossil fuels with renewable fuels for the kiln, the situation, based on Italian data, would be:

Table 9: expenses and revenues

		€/h
Fuel consumption	651.67 kg/h	- 312.80
Ammortization based on 8,000 h/operation per year over 8 years and maintenace		- 203.64
Subtotal expenses		- 516.44
Energy not bought from outside source	885 kWh	not considered
CO_2 certificates dryer	6,571.37 kg/h	13.69
Energy sold to grid	2,162.53 kWh/h	90.11
Thermal energy to brickyard		not considered
green certificates	2,172.22 kWh	162.92
white certificates	2.41 TEP/h	233.75
Subtotal revenues		500.47
Total		**-15.97**

All data based on actual Italian market prices.

Using a CHP system under the given conditions will result in an neglectible energy cost per kWh energy needed for the dryer and in a substantial reduction of overall costs due to the savings achieved not purchasing electric energy from the grid.

9 Conclusion

Decreasing the environmental footprint of the plant operation by substituting fossil fuels with renewable, even higher priced, fuels is results in a win- win situation for the company both from a financial as from an environmental point of view.

The substitution of traditional raw materials with selected waste materials and of fossil fuels with renewable fuels is an excellent example that “renewable” and “sustainable” does not have to the consequence of an increase in costs but can rather lead to substantial savings.

Incorporating a CHP system running on renewable fuels will even reduce the overall energy costs when compared to "standard fossil" conditions of operation.

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