LOW TEMPERATURE DRYING AND THE KYOTO PROTOCOL: A CASE STUDY

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INTRODUCTION

The emission reduction requirements established by the Kyoto Protocol pose an enormous challenge for the industrial world, and most particularly for the main industrial consumers of fossil fuels, such as, for example, the cement industry. In this type of industry, fuel costs exceed 30% of production costs. Consequently, for several years now, most of these industries have started implementing energy optimisation measures in their processes. To date, strategies have been based on the search for alternative fuels - classified as substitute fuels, e.g. sewage waste and biomass - so as to reduce the use of conventional fuels. Within this context, one of the primary objectives of this type of industry is both to make the supply and use of these substitute fuels reliable, and to search for innovative solutions that allow for new approaches to be introduced.

On the other hand, improved wastewater treatment processes and compliance with European water quality directives have led to a spectacular increase in the amount of sludge generated by wastewater treatment processes. Suitable management of sludge is therefore at present a major challenge. Competition between this type of waste and urban waste converted into compost, combined with stricter legislation, have reduced the possibilities for using sewage sludge for agricultural purposes. This fact, along with the ban on sludge direct disposal in landfills, has led to the search to optimise methods for deriving energy from sewage sludge, which, to date, have encountered economic drawbacks mainly due to energy consumption which can represent 30% to 50% of the total operational costs (Marchand 2004).

In the following an example of a complete integration of 2 processes is illustrated (namely sludge drying and the cement production) that results in significant environmental and financial synergies.

METHODS

Sludge recovery in the cement industry

According to Cembureau (1997), the EU cement industry produced in 1997 around 170 million tonnes of cement per year. As energy consumption represents 30-40% of the total production costs, many measures aimed at process energy improvements, the industry has made a significant investment effort over the past 20 years reducing energy consumption by 30%. One of these measures has been the use of substitute fuels: this allows the cement industry to improve its competitiveness and to make savings in the use of over 2.5 million tonnes of coal per year.

Using sewage sludge and other types of waste in the cement industry offers certain widely acknowledged advantages - irrespective of whether the resulting energy production is taken advantage of - due to the special characteristics of the cement production process. This explains the growing interest for this approach and its strong development over the past few years. The main advantages are:

- the use of alternative fuels reduces the use of fossil fuels in the cement production process, as well as avoiding CO_2 emissions which would have been to consider if other waste management routes were considered. This leads to a reduction in overall greenhouse gases emissions both for the cement industry and the waste management industry. For example Cembureau (1999) calculated that burning biofuel (resp. solvent waste) in a cement kiln allowed to reduce by 18% (resp. 21%) the emissions with respect to emissions which would have taken place if this waste was incinerated.
- the cement kilns´ increased energy efficiency by allowing for waste to be introduced directly into the clinker without the need for intermediate processing. Ash and other kinds of waste are not generated since these products are then incorporated in the cement.
- the cement kiln operating conditions – mainly working temperature, residence time and oxidation conditions – maximise the retention of potential pollutants (such as heavy metals) without reducing the quality of the main raw material, cement.

All of these general advantages apply in the case of sewage sludge. However, sludge has a water content of around 75-80% after the mechanical dewatering system, which does not usually manage to reach more than 30% dry matter content. This water content and its combustion drastically reduces the heating value of the sludge dry matter. For this reason, a prior drying stage is essential for the process to be considered operational and feasible.

Sewage sludge thermal drying

Sewage sludge thermal drying is based on the application of heat to evaporate any water that cannot be separated from sludge dry matter using mechanical methods. Given that the cost of heat energy is far higher than the cost of mechanical energy, it is crucial to optimise the prior mechanical dewatering process. As indicated in Figure 1, energy costs represent more than 50% of the financial cost of the thermal drying process. What this means is that only the more heat-efficient drying processes will permit an optimisation of overall treatment costs.

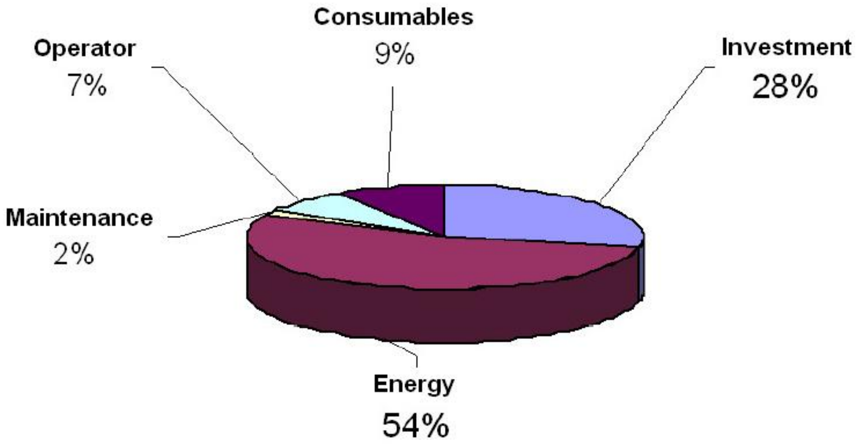

Figure 1 Thermal drying cost distribution.

The main purpose of the thermal drying process is to reduce the sludge water content. The aim is to considerably reduce, if possible *in situ*, the amount of sludge generated in the treatment plants so as to facilitate its subsequent management. Therefore, the thermal drying process favours a final use for sludge, reducing the amount of product that needs to be managed, and stabilising it and therefore facilitating its storage and handling, and increasing its calorific power. After thermal drying, sewage sludge has a lower heating value (LHV) of between 2,000 and 4,500 kcal/kg.

The STC sewage sludge drying process

The STC sludge thermal drying system is based on hot air convection at low temperature (65/80ºC) in a continuous closed tunnel. This system has been designed for drying sludge that has already been dewatered mechanically and for different kinds of biomass, and allows to reach a final dry solids content of 80-90%.

The sludge, stored in the receiving pit or silo, must be taken to the tunnel head, where the extruder granulates and distributes it evenly along the width of the belt providing better control over the drying process (this makes it easier for air to pass through the product mass in a uniform way). Moreover, as there is no movement or friction in the drying process, no dust is generated in this stage of the process.

The system comprises two belts. These belts convey along the tunnel, in which hot dry air circulates at a temperature of 65-80ºC and perpendicular to them. This air, propelled by the ventilation system, goes through the product extracting the water via hygroscopic equilibrium. The returned moist hot air is condensed in exchangers inside the tunnel, eliminating the water separated from the sludge and supplying new heat energy, so that the air is recirculated and the process is maintained in a closed air circuit.

It must also be noted that the low-temperature drying process prevents the stripping of other pollutants retained in the sludge, ensuring that they do not return to the water. As a result, only high quality water is obtained, with very low entrainments that depend on the kind of the sludge treated.

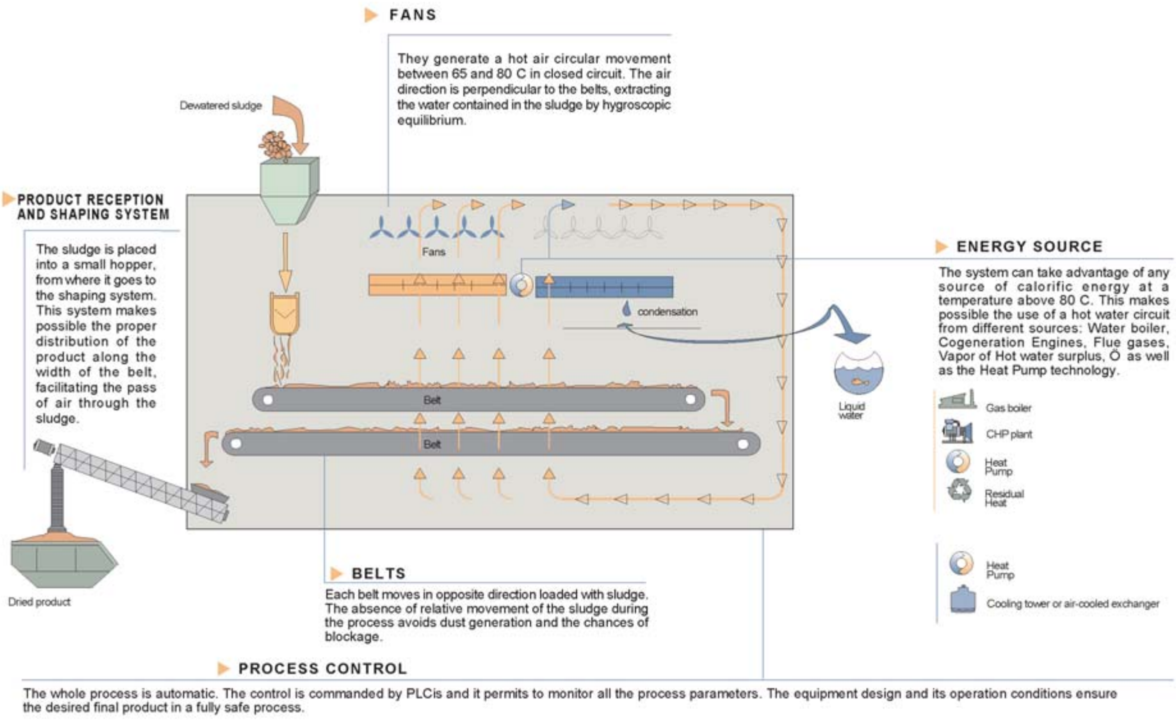

Figure 2 Flow chart of the STC thermal drying process

The STC drying process energy supply

One of the main innovative aspects of the STC dryer is its versatility regarding the heat source: it can operate with any hot energy source with a temperature above 80ºC. It can be adapted to operate based on a 75-90ºC hot-water circuit, whether produced by cogeneration engines, exhaust gas, residual vapour or hot water.

This working temperature, together with the closed air circuit, is one of the system's main advantages, as it allows several residual thermal energy sources - that may not be suitable for other types of processes - to be used. This is a critical factor to bear in mind, given the thermal energy costs in the overall drying process. Thus, all alternatives that allow for residual heat to be used for biosolids drying processes must be considered. The following are some of the more attractive alternatives for heat supply:

- cogeneration systems: not only exhaust gases are used, but also engine block heat (50% of the heat produced by a cogeneration engine), until the maximum efficiency permitted by the engine is reached.
- produced within other heat processes, such as exhaust from incinerator chimneys, turbine condensation heat, gases from gasification processes, etc.
- heat-pump or similar technologies can be employed.
- heat from renewable energy sources can be used, such as solar energy (hot water at 80ºC), geo-heat, etc.

As an alternative for maximising energy use and energy integration with other processes, STC has developed an approach to use residual gases from cement production processes, with a system that generates a 90/75ºC closed air circuit resulting from the exhaust gas exchange in the cement production process. Consequently, as all the energy used for the drying process comes from the cement production process, there is no need to consume primary energy, and this ultimately optimises the overall process.

Integration of the STC sewage sludge drying system within a cement production factory

The main energy sources available in cement factories are exhaust gases from kilns and/or cooling gases from clinkers, with flow-rates and temperatures varying from process to process. These gases can be classified as "dirty" gases (they contain many solid particles), for which reason they pass through highly efficient filters before they are emitted into the atmosphere. To ensure the filtering efficiency, most filter processes require these gases to be cooled down before they pass through the filter system.

RESULTS

Environmental and financial benefits of the integrated process

This type of process offers environmental advantages for all the parties: water agencies, companies managing sludge treatment plants, and cement factories as explained in the following

For water agencies, the management process is improved in environmental terms, since there is no need to locate a new site. It is also improved in financial terms, due to more efficient overall process management costs (as the final destination for the sludge is guaranteed) and reduced operational costs due to heat supply (since no primary energy source is required to carry out the process).

Companies operating sludge treatment plants benefit from an installation with an environmental impact that is compatible with the cement production, reduced energy costs (since primary heat energy is not required), preferential electricity costs, and a guaranteed final destination for sludge. In addition, this type of process does not rule out the use of other solutions, such as agricultural use or sludge disposal in landfill, as reductions in the quantity of product requiring handling and water content facilitate sludge management. As for environmental impact, the cement factory allows all sludge treatment plant equipment to be connected to a general deodorising network. Since the combustion of the off-take gases of the dryer takes place in the kiln, no odours are emitted to the atmosphere, making this one of the most effective odour treatment processes available, free of any capital or operational costs.

In the case of cement factories, the sludge thermal drying process allows for the overall efficiency of the production process to be improved by achieving more useful energy for the same primary energy consumption (which, moreover, implies a CO_2 quota). Moreover, the combustion of sewage sludge in the production process provides an additional CO_2 quota. The additional income from sludge management should likewise not be overlooked.

A case study: implementation in the Alicante cement factory

This type of system has been recently implemented in a cement factory near the city of Alicante (Spain) and is in the start-up process at this moment. A sewage sludge treatment plant has been installed in the cement factory and makes use of the same services installed for the latter, namely, lorry access zone, lorry weighing systems, gas emission measurement system, etc.

The plant treatment capacity is 60,000 t/year of sewage sludge collected from various WWTP, using residual energy from the cement production process. In this case, two dry-sludge treatment methods are planned - agricultural use and energy recovery - depending on the sources of the sludge and the time of year. The energy recovery corresponds to the use of the dried sludge in the cement kiln, as alternative fuel.

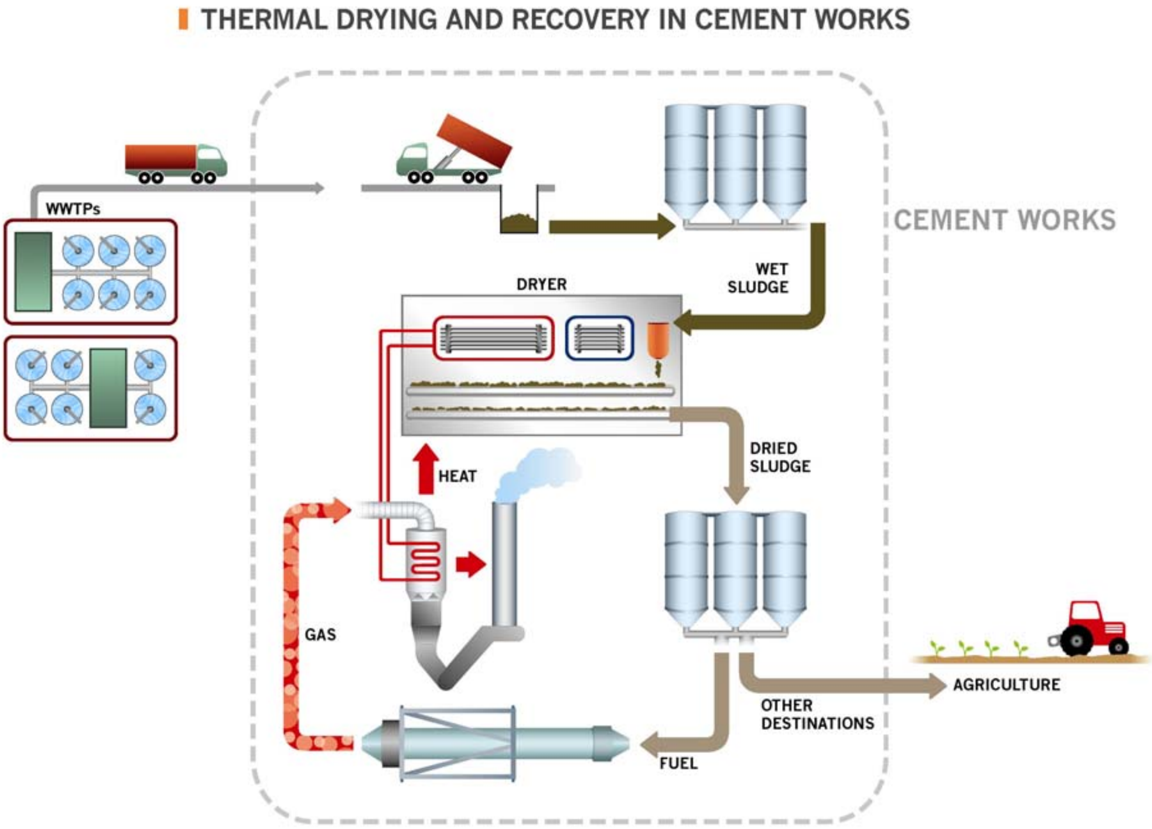

Figure 3 STC dryer – cement factory integrated system (Alicante, Spain)

The following environmental indicators can be achieved, based on a heat content for the substituted coal of 26 GJ/tn and a ratio of 93 kg of CO_2 per ton of coal:

- waste energy from the cement factory used for thermal drying the sludge, implying 46 million therms gained annually, equivalent to around 18,000 t of CO_2
- energy supplied by the sludge combusted in the kiln (mean calorific power of 3,000 kcal/kg of dry sludge) implying 53 million terms gained annually, equivalent to 20,500 t of CO_2

If these energy values are priced on the basis of a conservative cost of €0.01/therm of substituted energy and an estimated market value of €20/tn for CO_2, the financial value of these environmental improvements for the cement factory amounts to some €1,300,000. The income from sludge management can also be added to this amount. Likewise, the thermal drying process without primary energy consumption results in a saving of 46 million terms, implying additional financial savings of approximately €1,000,000.

CONCLUSIONS

Incorporating waste treatment processes in systems in which residual energy can be taken advantage of is one of the best residue management alternatives, given that the cost of energy is usually the factor that determines the feasibility and yield of a waste recovery project. Moreover, sludge energy recovery in cement factories is the only process that does not generate final waste (in the form of ash), since this becomes part of the cement end product.

This type of process provides an important environmental improvement opportunity for cement factories, since it increases energy efficiency; in other words, a greater proportion of useful energy for the same primary energy consumption effectively pre-empts the need to purchase CO_2 quota.

Sludge with a moisture content of less than 20% and acquired without primary energy consumption has an increased energy recovery potential. With a LHV of between 2,000 and 4,500 kcal/kg, it can be used as standard fuel, thereby reducing primary energy consumption and the CO_2 quota associated with substituted fuels.

This integrated sludge drying-cement production system has been assessed as a reliable, viable route for sludge management, allowing for significant reduction in greenhouse gases emissions both for the cement industry and the sludge drying process.

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