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Alternative Fuels and Cogeneration for Reducing CO₂ Emissions

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Abstract

Cogeneration is growing worldwide based on the burning of fossil fuels – especially natural gas. Although its low emission factors, it is important to consider that the availability of natural resources must be taken into account for a long-term investment in the energy generation sector. The identification of alternative renewable fuels and the integration of cogeneration to certain industrial processes that produce some of these alternative fuels are evaluated in this paper.

Key words: cogeneration – alternative fuels – CO₂ emissions minimization.

1 Introduction

Renewable sources of energy associated to cogeneration systems could not furnish all the energy demanded by the industrial processes that decide to use this generating alternative. However, its use may result, in the global sense, in environmental emissions and natural resources depletion reductions. In this way, it is imperative to evaluate the availability of alternative energetic resources and technical, economic and environmental parameters that are involved in their energy conversion process. Based on these aspects, the proposal of this article is to present some renewable alternatives and discuss its use associated to cogeneration systems.

2 Cogeneration

Cogeneration is defined as the combined heat and power generation for attending thermal heat and mechanical (or electrical) demands at the same time but with a single fuel (Balestieri, 2002). The alternative to cogeneration is to produce the thermal energy required to processes (boilers for producing steam and chillers for producing cold water, as example) and to purchase the electricity from the grid.

The first industrial units produced all the energy consumed because there was no electricity and thermal power stations to furnish that energy to the processes. This scenery was the reality in the United States and European Community until the beginning of 20th century, when electric transmission lines became economic feasible when compared to self-production. Although it is not a recent concept, cogeneration has been recently induced for representing a highly efficient energy conversion technology, not only because the thermal parcel to be rejected (in condensers, as example) is utilized in the production of thermal energy for process use, but also because of the reduction on environmental emissions that this technology represents.

There are several criteria for establishing the economic feasibility of a cogeneration project, and they depend on the sector in which the enterprise is to be connected: paybacks of less than two years are highly desirable for industrial projects, for example; however, cogeneration design payback typically is in the range of three to five years (Educogen, 2005). According to Olande (2004), "a payback period of 2 years or less is only possible when the average cost of electricity purchased from the utility is comparatively high or the average cost of fuel for the cogeneration system is comparatively low"; the ratio of purchased electricity to natural gas prices is considered a reasonable parameter for an economic analysis in the petrochemical sector (Milosevic and Cowart, 2002).

Although natural gas is environmentally desirable (compared to other fossil fuels) and has a consolidated market, its condition of non-renewable fuel must be considered. Several cogeneration projects based on gas turbine and heat recovery steam generator (HRSG) burns natural gas in the prime mover and use any available alternative fuel for burning in supplementary firing, if necessary because this last burner is only related to the process, not to the cogeneration process.

3 Alternative renewable fuels

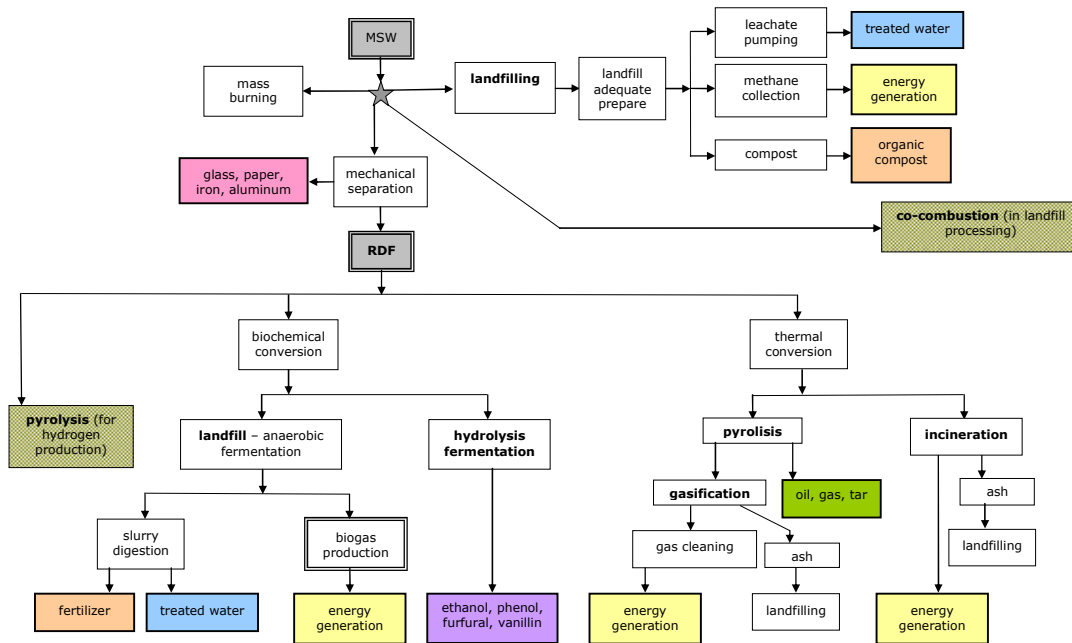
In some countries, space availability constraints imposed that severe municipal solid wastes (MSW) incineration policies were established. A country in which the population density is high, such as Japan, which presents 343 inhabitants/km² (Ministry of Internal Affairs and Communications, 2005), the incineration approaches to 100% (Rosa, 2003) and is mandatory.

Some alternative energy sources, such as biomass (that includes MSW, sewage, vegetal residues from forestry and agriculture, and animal residues), industrial residues and hydrogen (an energy carrier, in reality) must be considered in terms of their economic and environmental feasibility, as well as the potential of mitigation/reduction of CO₂ emissions. These options are connected not only by the technological viewpoint (they utilize certain common technologies, such as gasification) but also in the economic sense because if one route of conversion is assumed, the alternative options are discarded (it is the case of incineration and landfilling, for example). The continuously growing of MSW and sewage residues production imposes energetic and environmental interventions.

3.1 Solid wastes

According to Fiorucci et al. (2005), from the total MSW that is available as input, fractions are distributed to each unit and, since a parcel is designated to some processing route, it will have a specific destination, and certain final products – and not some others – will be obtained. In Fig. 1 it is presented some possibilities of MSW processing, and also its interfaces with sewage processing and hydrogen generation. The chemical structure C₆H₁₀O₄ is a reasonable representation of MSW structure (Cohen, 2004).

If destroyed without prior processing, MSW is referred as "mass burn". In this case, a minimum processing is needed for removing non-combustible items and there is no energy generation. Landfilling may be done both for processed and non-processed MSW. After mechanical separation of MSW for collecting recyclable products, an energetic product named residue derived fuel (RDF), is obtained. Some commercial products may also be obtained: fertilizers, treated water, chemical products such as ethanol, phenol, furfural, vanillin and others.

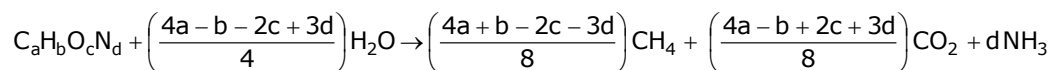


Modified from Pipatti and Savolainen (1996); Fiorucci *et al.* (2003), Küçük e Demirbaş (1997); Kumar (2000)

Fig. 1 – processing and products of MSW

According to EPA, the USA Environmental Protection Agency, incineration is defined as the destruction of solid, liquid and gaseous wastes by using heat in a controlled combustion process (Cohen, 2004). Brunner (1994) amplifies the above definition by declaring that incineration is the process of thermal destruction in which the waste is degraded to a non-putrescible condition by applying and maintaining heat sources. In a technical sense, RDF incineration reduces wastes volume and may be adequately burned in waste-to-energy plants for producing steam and electricity, although the thermal efficiency of such systems are not high (in the range of 10 e 15%) and residence time of 2 seconds at 850°C are mandatory in the furnace.

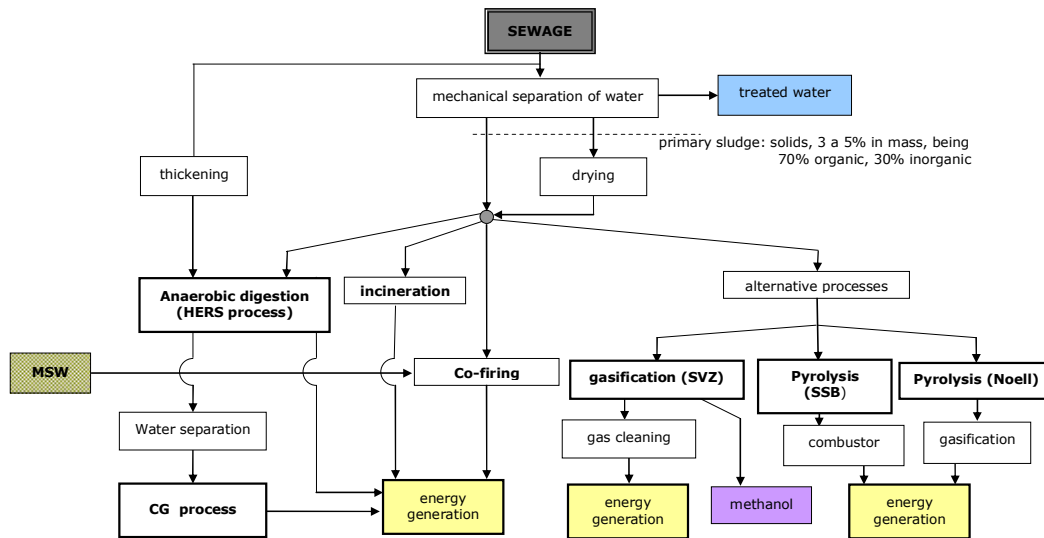
Landfilling is the process of disposing solid wastes and some other wastes according to technical and environmental good practices. It is also considered the least cost technical alternative for waste disposal, but not necessarily it is the best environmental choice. The anaerobic transformation of organic fractions in a landfill may be described by the following chemical reaction, assuming that the biodegradable portion of organic matter may be completely stabilized and that this happens in the presence of moisture (Tchobanoglous and O'Leary, 1994):



A preliminary evaluation of 50% of all methane generated in a landfill is recovered and burned, and 15% of lost methane is oxidized in the landfill cover (Finnveden *et al.*, 1995). Pipatti e Savolainen (1996) utilized an efficiency of 40% for landfill methane collection. Some other interesting values from the same reference: landfill produces 60 kg of CH₄ per ton of dry waste, or 42 kg of CH₄ per ton of moisture waste, or 214 kg of CH₄ per ton of degradable organic carbon of waste.

3.2 Sewage

For Küçük and Demirbaş (1997), biomass conversion routes may be structured by thermal/thermo chemical, biochemical and chemical processes. In the case of MSW conversion, all of them are present, being hydrolysis corresponding to chemical route in Figure 1. Energy generation is obtained by means of landfill gas collection and incineration, pyrolysis or gasification of RDF. The use of RDF for hydrogen generation is proposed by Wallman *et al.* (1998), as well as the co-combustion of MSW and slurry (Werther and Ogada, 1999). Figure 2 presents the processes of sewage treatment for energy generation and some other products.



Adapted from Werther and Ogada (1999)

Figure 2 – sewage processing and corresponding products

Anaerobic digestion, incineration, co-firing and alternative processes such as pyrolysis and gasification are the most prominent in the sewage processing for energy production. Co-firing of sewage and MSW is an alternative that integrates two highly available and renewable energy sources.

In sewage systems, there are equally important portions, the biogas production and the solid waste. For Shen and Zhang (2005), the analysis of sewage solid waste at 5% of moisture and organic matter under decomposition at 4.2% of moisture reveals a higher heating value of 20.90 MJ/kg and 15.76 MJ/kg, respectively. For Brunner (1994), sewage solid waste is generated in a rate of 90 g/inhabitant.day; as this is a reference that does not consider food characteristics and population habits, a range between 70 to 100 g/inhabitant.day is reasonable for evaluating the availability of such energy source for energy generation planning studies.

From the environmental point of view, biochemical systems are the most promising sustainable alternatives for reducing carbon dioxide levels (Küçük and Demirbaş, 1997). Biomass may be considered a carbon sink or a way for directly substituting fossil fuels without a net contribution of atmospheric CO₂ in the case of its sustainable production. For Slupek *et al.* (2000), NO_x, CO and particulates production are 0,87kg_{NOx}/ton (~0,09 g_{NOx}/MJ), 1,13 kg_{CO}/ton (~0,12 g_{CO}/MJ) e 0,021 kg_{particulate}/ton relatively to the burning of 1 ton of sewage solid waste.

3.3 Industrial opportunities

Several industries present renewable fuels that can be considered for substituting fossil fuels in their energetic matrix. For the petrochemical industry, to particularize a specific sector, there are opportunities associated to the use and production of hydrogen. The concept of cogeneration of power and hydrogen is attractive for the petrochemical sector because the use of both – especially hydrogen – is very high: catalytic hydrocracking consumes 362.103 to 904.103 MJ/bbl of crude oil and catalytic hydrotreating consumes 235.103 MJ/bbl of crude oil (DOE, 1998).

Nowadays, the care devoted to the reduction of CO₂ emissions is mandatory, and in the petrochemical industry it is a special worry for which the attractiveness of some more efficient advanced technologies may be reduced in the case of augmenting CO₂ emissions; fortunately, advanced technologies under development are based on cogeneration concepts, whose premises involve more produced thermal and electric power with less fuel combustion.

For becoming a reality, gas turbine and combined cycle energy generation must be developed. The HyGenSys process (HPI, 2005) by Institut Français du Pétrole is based on the conversion of natural gas to hydrogen in a steam reformer to be burned in a generating system. For the implementation of such technology, gas turbines specially adapted for hydrogen burning must be developed. Bannister, Newby and Yang (1998) present some aspects of gas turbines adaptation for operating at thermal efficiency of at least 70,9% (based on lower heating value) as part of International Clean Energy Network using Hydrogen Conversion program.

4 Conclusions

Natural gas market is perceived by the industrial sector as an efficient and environmentally justifiable fuel; however, its price structure and the need of including renewable sources in the countries energy matrix impose the search for new alternatives. The production of gaseous and solid fuels from the adequate conditioning of sewage and MSW together with the availability of industrial opportunities of generating certain alternative fuels may be viewed as environmentally adequate for its integration to the cogeneration concept, which may become more attractive by the use of waste energy.

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