A Comparative Study of the Gasification Technology *versus* Traditional Combustion Technologies for Power Generation in Mexico

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ABSTRACT

A study of the gasification technology versus traditional combustion technologies for power generation was performed in order to present the cost-benefit of them, also, to verify the applicability of the gasification technology in the power generation in Mexico.

At the moment, the gasification technology is not applied in the power generation in Mexico. However, seen the importance of its worldwide application, there has been an increasing interest from the main power energy company, Comision Federal de Electricidad (CFE) and the main oil company, Petroleos Mexicanos (PEMEX) in the potential use that the gasification technology offers as an alternative for power generation. In addition, the technology allows synergies to other industries, the diversification in the use of different fuels, ultra low contaminant emissions, the used of the capture and sequestration of CO_2 technology, among others.

It is well known that the gasification technology as Integrated Gasification Combined Cycle (IGCC) become an attractive technology since it offers a clean path to power generation and flexibility on the feedstock, giving as a result a wide fuel diversification to be used in power plants.

The combustion technologies considered on this study were, subcritical pulverized coal (PC) and heavy fuel oil (HFO) steam plants, supercritical pulverized coal (SPC) steam plants, circulating fluidised bed (CFB) steam plants and natural gas combined cycle (NGCC) plants. The simulation of the power plants on this study was performed by means of Thermoflow Inc. software. In the case of IGCC plants, different feedstock, such as coal, petroleum coke and heavy fuel oil were included in the evaluation.

The comparative study was performed on the base of a techno-economic evaluation in function of the operative parameters and technical factors such as plant location, power energy efficiency, requirement of water process, emissions, etc. and, economical factors such as investment, fuel costs, etc. The results have shown that the application of the IGCC technology can be considered as an attractive alternative for power generation in Mexico, since it offers several advantages over the traditional combustion technologies.

Keywords: Electric power generation, IGCC, Gasification, Traditional combustion technologies, Fossil fuels, Efficiency, Costs

INTRODUCTION

It is well known that the electricity demand have been growing around the world. In Mexico, that situation is not an exception, and as a result, there is a permanent scheme for an expansion in the current power plant fleet (SENER, 2006).

However, the volatility prices of natural gas and crude, also the worldwide needs to reduce the greenhouse gas emissions point out a clear path to explore alternative technologies for power generation.

In past years, the Instituto de Investigaciones Electricas (IIE), considered as the technological research arm of the Energy sector in Mexico, has performed several studies of the gasification technology as Integrated Gasification Combined Cycle (IGCC) for power generation (Manzanares-Papayanopoulos, 2006; Fernández-Montiel, *et. al.*, 2003; Fernández-Montiel, 1994; Fernández-Montiel and Alanis, 1993 and 1994).

In a previous paper (Manzanares-Papayanopoulos *et. al.*, 2006), the study of the syngas production analysis as a function of fuel compositions, temperatures and pressures by simulation carried out by commercial computational packages, and the comparison of the energy produced as function of the fuel composition at the same operational parameters was presented. Additionally, a design of an atmospheric pressure gasification system at work-bench scale to gather information of the kinetics gasification process has been also presented (Altamirano-Bedolla *et. al.*, 2007).

The IGCC offers flexibility of the fuel used and with a required pollution reduction systems allows clean power generation (Higman and Der Burgt, 2003; Rezaiyan and Cheremisinoff, 2005).

There are other comparative studies of the gasification technology. Zheng and Furinsky (2005) have presented a comparative study in function of the features of four gasifiers used in an IGCC plant scheme. In other hand, Beér (2007) reviewed different electric power generation systems as a function of the plant efficiency; and Ordorica-Garcia *et al*. (2006) have presented a technical and economic comparison of the performance simulation of four IGCC plant designs with different levels of CO_2 capture against a NGCC plant without CO_2 capture.

In this work, the comparison of the IGCC performance against the most common traditional combustion technologies for power generation in function of the feedstock available in the Mexico is presented.

CASE DESCRIPTION

The traditional combustion plants for power generation considered for this study were two subcritical steam plants fed with pulverized coal (PC) and with heavy fuel oil (HFO), one supercritical pulverized coal (SPC) steam plant, two circulating fluidized bed (CFB) combustor plants fed with PC and with petroleum coke (petcoke), and a natural gas combined cycle (NGCC) plant.

The site conditions were also considered, since the efficiency of the gas turbines are affected due to the altitude. The technical evaluation analysis was performed for two feasible sites in the country, on-shore and in the mainland. The site conditions are presented in Table 1. The analysis of the feedstock available in function of the technology studied for each site is presented in Table 2.

Table 1 Site ambient conditions for the technical evaluation of the power generation plants

Site	Maximum Ambient Temperature	Design Ambient Temperature	Altitude	Atmospheric Pressure	Relative Humidity	Wet Bulb Temperature
Units	**(°C)**	**(°C)**	**(m)**	**(bar)**	**(%)**	**(°C)**
Mainland	36	33	1,589	0.844	32.62	20
On-shore	41.0	37	10	1.012	42.25	26

Table 2 Feedstock available in function of the site and the technology of the power generation plants

Site	Available Fuel	Technology
Mainland	Natural Gas	Combined cycle
	Petroleum coke	Fluidized bed
	Heavy fuel oil	Subcritical steam plant
On-shore	Natural Gas	Combined cycle
	Petroleum coke	Fluidized bed
	Heavy fuel oil	Subcritical steam plant
	Coal	Subcritical steam plant Fluidized bed Supercritical steam plant

The energy production capacity of the plants was of 700 MW (+/- 15%). The steam turbine cooling for the plants situated mainland was via aero-condensers, and for the plants situated on-shore was via sea water.

In reference of the premises for the economical evaluation, these are described as follow. The equipment cost of the plants was obtained directly for the Thermoflow software programs used in the technical and economical evaluation. The evaluation assumes a plant life of 30 years, a rate of return of 12%, a load factor of 80% to fix the comparative basis for the IGCC with the others technologies.

Figure 1 shows the price scenario of the feedstock for 30 years used in the economic evaluation of the technologies. The dotted line is the critical line of the fuel cost used in a IGCC plant in function of the cost of a NGCC plant (Jones and Shilling, 2002), i.e. below the dotted line any fuel costs make the IGCC plant economical attractive and above the dotted line the IGCC is not economical attractive. Coal 1 is from Colombia and Coal 2 is from Australia. The heavy fuel oils and the coke are from the Mexican refineries.

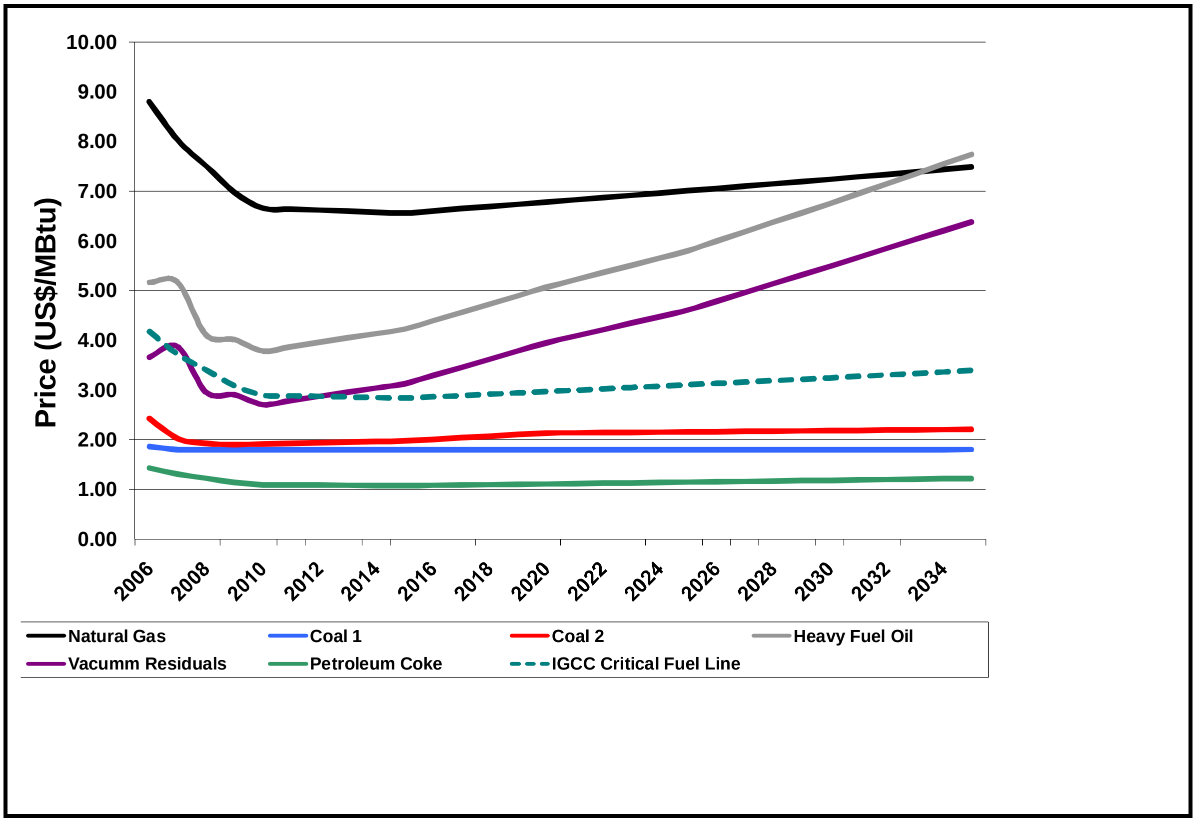

Figure 1 Price scenario to up 30 years of the feedstock available for the power generation plants in Mexico

RESULTS

The analysis of each technology was carried out in base of the plant performance. In function of that performance, a capital cost (initial investment) was associated for each plant. Figure 2 and Figure 3 shown the capital cost for the plants situated mainland and on-shore, respectively.

In both Figures, the lower investment cost is for a NGCC plant. However, the following attractive option in mainland for investment becomes the IGCC plant operated with heavy fuel oil. However, the first attractive IGCC plant for investment on-shore is until the fourth option presented in Figure 3.

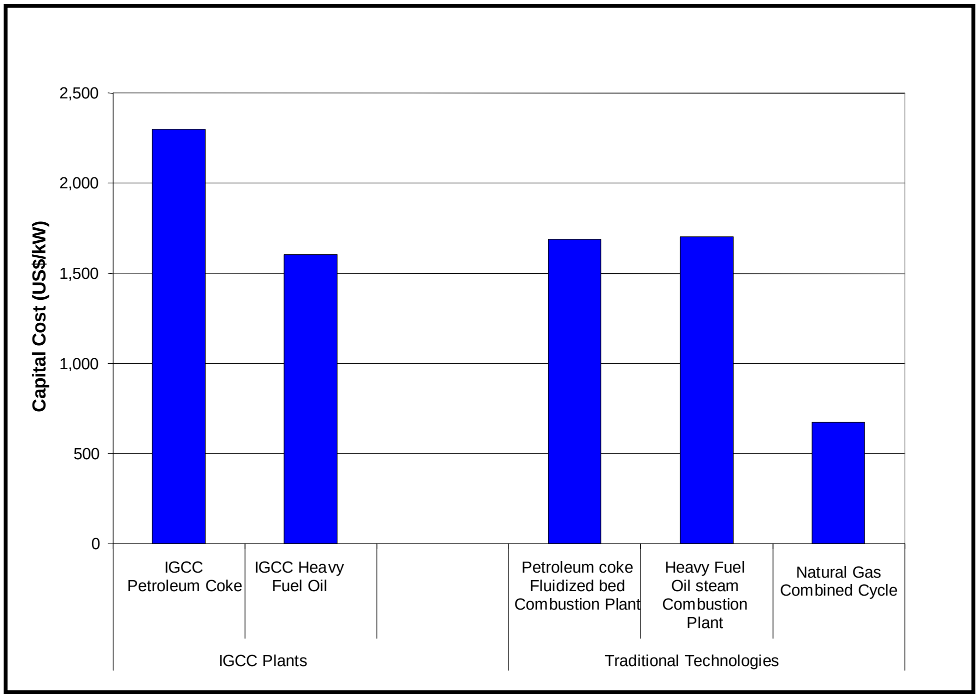

Figure 2 Direct capital costs of IGCC plants and traditional combustion plants in mainland

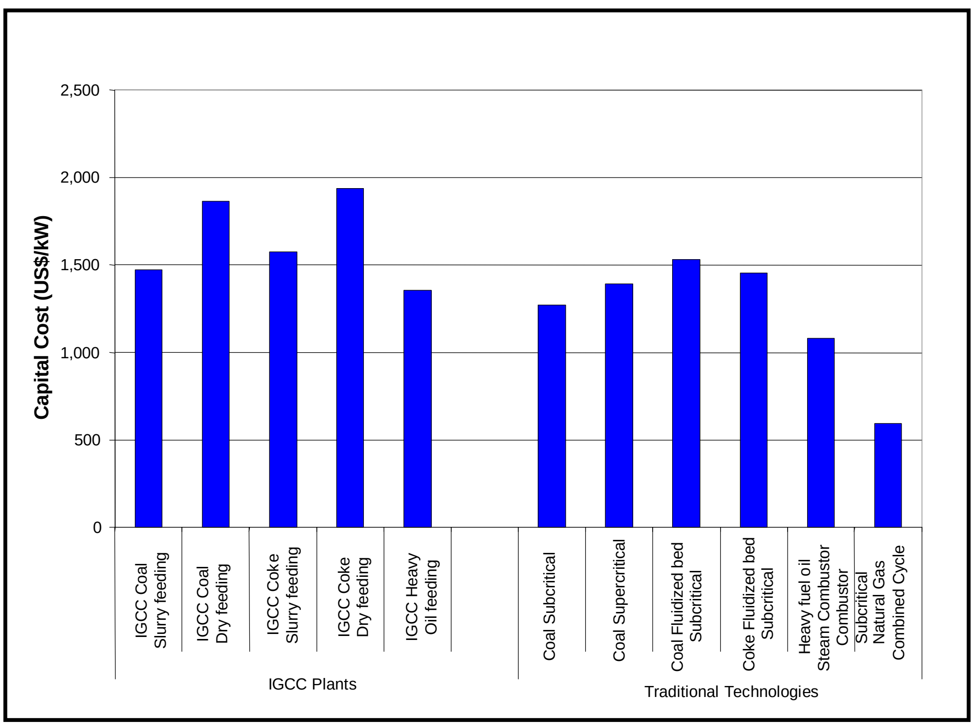

Figure 3 Direct capital costs of IGCC plants and traditional combustion plants on-shore

An interesting outcome on these Figures, it is that using the petroleum coke as feedstock results the highest inversion required to build an IGCC power generation plant. Since the petcoke from Mexican refineries has high levels of sulphur content, the cleaning systems needed to remove the sulphur are bigger.

A more deep analysis had required to include the indirect costs, i.e. power generating costs. Figures 4 and 5 present a comparative plot of the required investment costs including the operative costs (fuel, maintenance and operation costs) of each technology for the plants situated mainland and on-shore, respectively

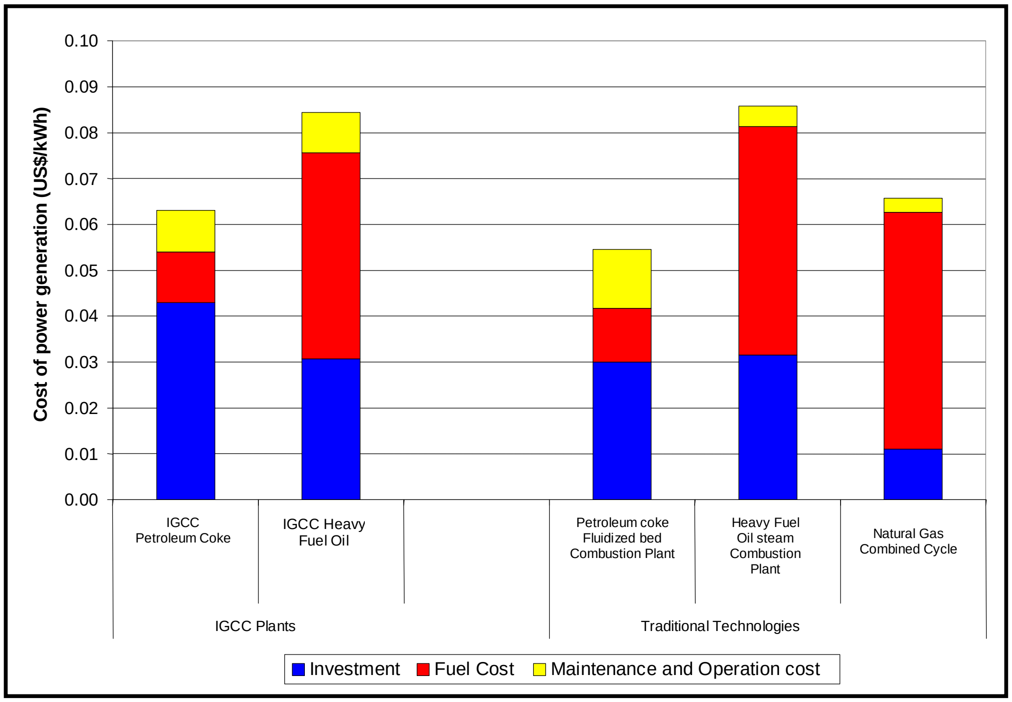

Figure 4 Comparative graph of the required investment costs including the operative costs of each technology for the plants situated mainland

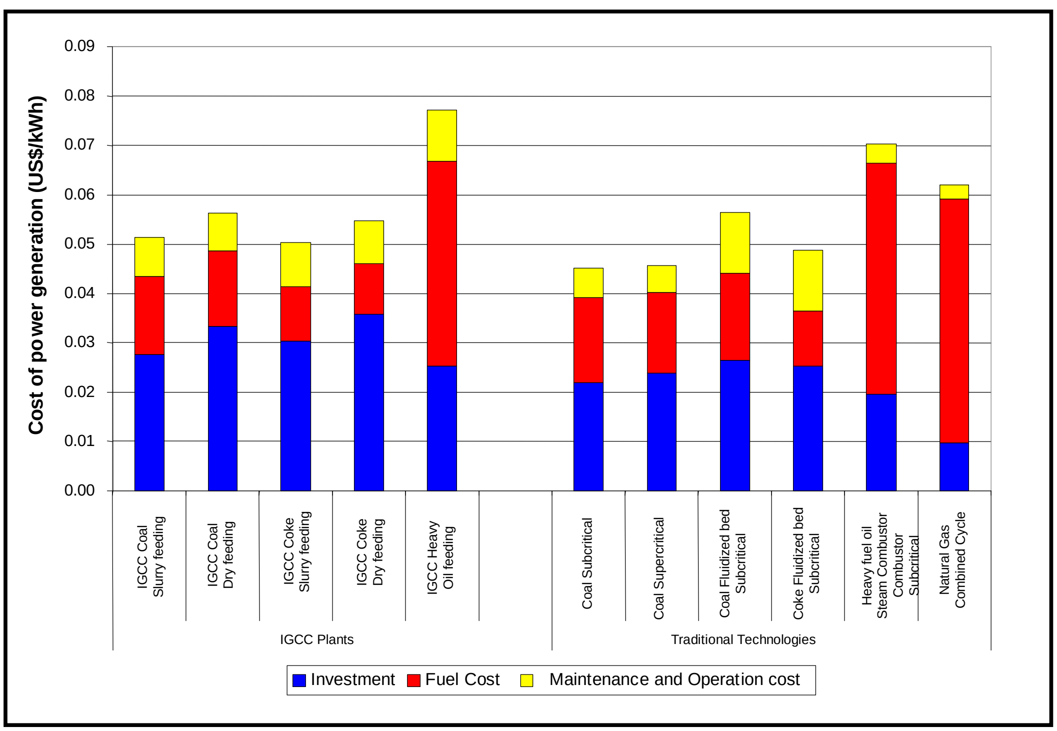

Figure 5 Comparative graph of the required investment costs including the operative costs of each technology for the plants situated on-shore

The outcome of the plant cost including the indirect costs pointed out that the analysis must be carry out including all the costs involved in the construction, maintenance and operation of a power generation plant. In the case of the plants situated mainland, see Figure 4, the option more attractive is the circulating fluidized bed combustion plant using as feedstock the petroleum coke. As a second option become the IGCC plant using also as feedstock the petroleum coke. The NGCC plant was the first option for just the investment cost point of view. However, due to the actual cost of the natural gas and the increasing cost scenario, the NGCC plant becomes as a third attractive option.

A same situation results for the analysis of the power generation plants on-shore, as shown in Figure 5. Four of five IGCC options are more attractive than the natural gas combined cycle plant. However, coal subcritical and supercritical steam generation plants are the most attractive options on-shore for power generation investment.

CONCLUSIONS

There are many conclusions from the work presented here. The technical evaluation pointed out that for a 700 MW IGCC plants three independent lines of syngas production are needed, and to have higher operational flexibility should be better do not have an air integrated system. Also, if the disponibility of an IGCC plants want to be higher then the plant most considered a spare gasifier. However, this action will increase the capital cost about 8.3%. In reference to the emissions, the IGCC plants are good option since they have similar emissions than a natural gas combined cycle plants without take care of the nature of the feedstock used.

The combination of the technical and the economical evaluation of the IGCC plants are presented next. The best option for an IGCC plant is the one presented on shore using petcoke slurry as feedstock, due to the low cost of the petroleum coke. Nonetheless, the IGCC plants are attractive in both sites on-shore and mainland, the pulverized coal subcritical and supercritical steam combustion plants are the best options for an investment. This is due to the evaluation of these coal plants was performed without desulphuration equipment since the emissions are inside of the environment normativity.

The outstanding result here is that the IGCC plants are competitive options against the natural gas combined cycle, and then it become important since the IGCC technology has the flexibility of the used different kind of fuels. However, in spite of the advantages of the IGCC technology, the natural gas combined cycle plants are more attractive since the capital cost will return in less time than the capital cost of the IGCC plants.

Finally, as an strategy of reducing costs, the Gasification Technology should be considered to be used in different synergies with other industries such as the oil industry, since there are different industrial processes than can take advantages of the subproducts obtained from this technology or to use the syngas as a feedstock to other industrial process as the Fischer-Tropsch process to obtain diesel and gasoline.

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