

## IGCC: An alternative to the use of mineral coal

Neto, J. M.<sup>1</sup>, Ando Junior, O. H.<sup>1</sup>, Spacek, A. D.<sup>1</sup>, Oliveira, M. O.<sup>2</sup>, Schaeffer, L.<sup>2</sup> and Bretas, A. S.<sup>2</sup>

<sup>1</sup> Department of Electrical Engineering

**SATC**, Beneficent Association of Santa Catarina Coal Industry

Pascoal Meller Street, 73. Criciúma-Sc (Brazil)

Phone/Fax number: +55 48 3431-75.50, e-mail: [joao.neto@satc.edu.br](mailto:joao.neto@satc.edu.br), [oswaldo.junior@satc.edu.br](mailto:oswaldo.junior@satc.edu.br),  
[anderson.spacek@satc.edu.br](mailto:anderson.spacek@satc.edu.br)

<sup>2</sup> School of Engineering

UFRGS, Federal University of Rio Grande do Sul

Av. Osvaldo Aranha, 103. Porto Alegre-Rs (Brazil)

Phone/Fax number: +55 51 3308-31.29, e-mail: [moliveira@ece.ufrgs.br](mailto:moliveira@ece.ufrgs.br), [schaeffer@ufrgs.br](mailto:schaeffer@ufrgs.br), [abretas@ece.ufrgs.br](mailto:abretas@ece.ufrgs.br)

### Abstract.

The expectation of reducing reserves of non-renewable resources, as well as the growing concern for environmental preservation has been encouraging the substitution of conventional resources and technologies in electricity generation by alternatives for higher performance and / or renewable sources. In this context, the gasification of coal is gaining ground because of technological developments, enabling the generation of electricity cleanly and with greater efficiency when compared with consolidated thermoelectric plants. From these premises, this paper will address the national energy demand growth, cost analysis and deployment of IGCC technology comparison with other economic means of generating clean.

**Key Words:** Electricity Generation; Coal; IGCC.

### 1 INTRODUCTION

The countries in economic growth have in common the need for energy resources as a basis for increasing the productive sector. Sustainable development is also a relevant factor in the analysis of this expansion, minimizing the environmental impact that man has on the planet.

Among the non-renewable energy resources in the world, coal occupies first place in abundance and perspective of life, which is estimated at 200 years, standing out as the main source compared to oil and natural gas, which present life useful, 40 and 65 respectively. In the composition of the global energy mix, coal is positioned below the oil, however the generation of electricity is the leading global resource.

As indicated in the 2010 energy balance of the Ministry of Mines and Energy the production from coal is located in

the southern region of Brazil, where the state of Rio Grande do Sul holds 3.094 million tones, Paraná and Santa Catarina 2,522,000 93,000 . Since the projection of the share of coal in the national energy mix in 2023 will reach the level of 5.35%.

However the main obstacle to increasing the share of coal in the national energy matrix is due to the fact that today most countries makes the power generation through direct combustion of the fuel. This process generates high amounts of greenhouse gases, which contribute to global warming. Coal will still be widely used for electric power generation, considering its low price, high availability and distribution of fuel.

Aiming to increase the use of coal for electricity generation in accordance with environmental regulations in force the scientific community is developing new technologies. Among these stands out the IGCC (Integrated Gasification Combined Cycle) that presents the greatest possibility of deploying industrial scale due to its techno-economic costs.

### 2 NATIONAL SURVEY OF ENERGY CONSUMPTION

According to data from the Brazilian Electric Power Company ("ELETROBRÁS"), the electricity consumption in Brazil grew more than 1,100% over the past 40 years, at an average rate of 6.75% per annum. The most significant growth occurred in the 70s, a period called the "Economic Miracle", when energy consumption grew at rates of over 10% per year. Being the hydroelectric primarily responsible for the growth in domestic demand. However it is necessary to diversify the energy to ensure stability in the supply and avoiding "blackouts".

The electricity consumption in 2010, according to EPE (Energy Research Company), was 419,010 GWh, a value that is slightly above expectations, but should take into

account variations in annual demand according to the growth and development of country. The fact is that demand grows increasingly over the years, emphasizing the importance of the establishment of new units and diversification of the national energy matrix.

Table 1 shows the projection of national energy demand from 2011 to 2015, considering two scenarios for average annual growth of the Brazilian economy, from 4.87% to 5.04% and underperforming favorable economic scenario (REGO, 2004). For this calculation we considered all types of consumers, namely: industrial, residential, commercial, rural, lighting and public service.

Table 1 – Projected Increase of Demand

	2011	2012	2013	2014	2015
Low Demand (GWh)	438.610	460.443	478.002	503.783	531.798
High Demand (GWh)	444.263	467.118	485.776	513.017	542.525

The electricity consumption in 2010, according to EPE, was 419,010 GWh, a value that is slightly above expectations, but should take into account variations in annual demand according to the growth and development of the country. The fact is that demand grows increasingly over the years, as shown in the projections for 2015, highlights the importance of deploying new units and diversification of the national energy matrix.

### 3 IGCC PROCESS DESCRIPTION

In the last decades the gasification process began to spark interest in the electricity sector, because of the rise in technology called Integrated Gasification Combined Cycle. This has some advantages, such as lower greenhouse gas emissions compared to conventional thermoelectric unit, has a high thermal efficiency and ability to capture and store carbon. [13]

Sets up IGCC (Integrated Gasification Combined Cycle - with Integrated Gasification Combined Cycle) as a process for generating electricity through coal gasification, through gas and steam turbines, and the novelty lies in integrating these turbines for electricity generation.

The IGCC has been developed from the combination of two technologies: power generation in combined cycle and gasification of solid fuels, as illustrated in figure 1.

The generation combined cycle stands out for its high efficiency. While the nominal efficiency of a thermoelectric plant in simple cycle gas reaches 33% to 42% in combined cycle generation efficiencies are achieved nominal 59%, referring to the lower calorific value (DOLEZAL, 2001).

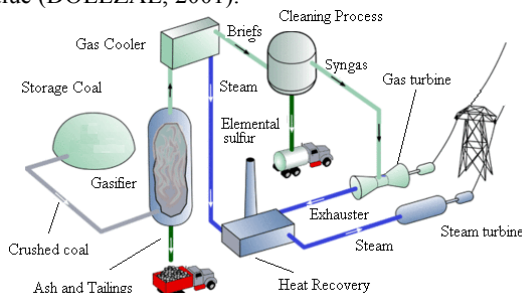


Figure 1 - Integrated gasification combined cycle.

### 3.1 INVOLVED COSTS IN ELECTRICITY GENERATION THROUGH IGCC

This item will be given the cost of electricity generation produced by IGCC technology, which uses coal as fuel. It is noteworthy that the costs presented does not include the carbon capture system. Thus, we analyze the plants that were designed as the basic structure shown in Figure 1 and used the CI method (Cost of Investment) that results from the total plant cost (TPC) plus the total capital requirement (TCR) to estimate the costs based on the rated capacity (\$ / kW). Table 2 shows the cost of electricity per kW, using data obtained from EIA (2010, p.7) and Ortiz (2011, p.110), based on the CI method.

Table 2 – Electricity cost through igcc per kw.

	Nominal Capacity (kW)		
	200.000	600.000	1.200.000
Investment Cost(2010\$/kW)	US\$ 2,569	US\$3.565	US\$3.221
Fixed Cost of O&M <sup>1</sup> (2010\$/kW)	US\$ 35,90	US\$59,23	US\$48,90
Variable Cost of O&M <sup>2</sup> (2010\$/MWh)	US\$ 6,87	US\$6,87	US\$6,87
Total Cost (2010\$)	US\$ 0,5 Bilhões	US\$ 2,139 Bilhões	US\$ 3,865 Bilhões

According to Hoffman (2010), the CI includes costs that relate to the installation of a plant with IGCC technology, usually expressed as the total cost per rated capacity, is ideal for making the comparison with the costs of plants of different sizes. TPC is included in the installation cost of the plant as process equipment, direct labor and indirect, design, construction and project management. The TCR includes the TPC, the value of money over time, the costs of start-up and owner.

IGCC small plants in order to demonstrate the functioning technology. When planned for commercialization, become extremely unviable. According to EPRI (2005, p.26), "The costs linked to a 2MW plant would be around 32.3 million dollars". However plants with higher capacity are in commercial operation.

### 3.2 COST OF ELECTRICITY GENERATION THROUGH WIND AND SOLAR POWER

There is a growing interest in developing renewable energy from solar and wind technologies, due to the environmental benefits, energy security and that these provide. Fact that makes renewable energy attractive to investors. Despite these and other benefits, problems related to costs have encouraged the development of this matrix prevented large-scale (*National Renewable Energy Laboratory*, 2008).

<sup>1</sup> Operation and Maintenance. Includes the following expenses: Owner, expenses not related to fuel, maintenance of gas turbines and steam, balance of plant, generator and HRSG.

<sup>2</sup> Operation and Maintenance. Includes the following expenses: Consumables & Supplies, lubricants and water.

The use of solar radiation potential and kinetic energy of the wind, as an energy source is an option able to assist in providing electricity with low carbon economies. However, it would be necessary to make changes throughout the sistema electric widely to explore the renewable energy sources available. The generation of electricity using solar and / or wind are technologies that dispute space in the global energy market, as well as IGCC technology. The purpose of such technologies is a generation without the emission of gaseous pollutants emitted by conventional thermal units. As a way to show the difference of the cost related to the generation of kW between renewable technologies discussed in this article, was elaborated the Tables 3 and 4, for comparison of the costs associated with these technologies, where the fixed costs of operation and maintenance, are for the owner's expense, maintenance and possible replacement in auxiliaries, generator and turbine.

Table 3 – Cost of Wind Power per kw.

	Nominal Capacity (kW)		
	50.000	100.000	200.000
<b>Cost of Investment (2010\$/kW)</b>	US\$ 1.896	US\$ 2.438	US\$ 2.313
<b>Fixed Cost of O&amp;M (2010\$/kW)</b>	US\$ 30,92	US\$ 28,07	US\$ 25,33
<b>Variable Cost of O&amp;M (2010\$/MWh)</b>	US\$ 0,00	US\$ 0,00	US\$ 0,00
<b>Total Cost (2010\$)</b>	US\$ 94,8 Million	US\$ 243,8 Million	US\$ 462,6 Million

Table 4 - Cost of solar electricity per kw.

	Nominal Capacity (kW)		
	500	7.000	150.000
<b>Cost of Investment (2010\$/kW)</b>	US\$ 8.030	US\$ 6.050	US\$ 4.755
<b>Fixed Cost of O&amp;M (2010\$/kW)</b>	US\$ 31,12	US\$ 26,04	US\$ 16,70
<b>Variable Cost of O&amp;M (2010\$/MWh)</b>	US\$ 0,00	US\$ 0,00	US\$ 0,00
<b>Total Cost (2010\$)</b>	US\$ 4,015 Million	US\$ 42,35 Million	US\$ 713,2 Million

#### 4 DISCUSSION AND ANALYSIS OF THE RESULTS

Having premised on the environmental issue, the deployment of an IGCC unit presents as a positive addition to CCS (Carbon Capture and Storage - carbon capture and storage) systems, providing other advantages such as low emissions of sulfur compounds and mercury, as well as greater flexibility in relation to inputs and process products. Thus we have two products to market: electricity and carbon credits.

When compared with solar and wind energy (see Table 5) IGCC technology has proven to be competitive only in relation to solar power, which despite having no variable cost of operation and maintenance, has high investment cost.

Even with an investment cost similar to that of wind and solar energy below the cost of maintenance and operation significantly increases the cost of an IGCC plant. Despite this fact, the cost of electricity in IGCC level proves to be less when compared to solar.

Looking For compare costs related to deploying units of electricity generation through wind, solar and IGCC, was elaborated in Table 5 and 6, in order to determine which technology has lower cost, having the same capacity, *i.e.*, average of 200 MW.

Table 5 – Comparison of technologies.

	Technology Type		
	IGCC (200MW)	Wind (200MW)	Solar (150MW)
<b>Cost of Investment (2010\$/kW)</b>	US\$ 2.569	US\$ 2.313	US\$ 4.755
<b>Fixed Cost of O&amp;M (2010\$/kW)</b>	US\$ 35,90	US\$ 25,33	US\$ 16,70
<b>Variable Cost of O&amp;M (2010\$/MWh)</b>	US\$ 6,87	US\$ 0,00	US\$ 0,00
<b>Total Cost (2010\$)</b>	US\$ 513,8 Milhões	US\$ 462,6 Milhões	US\$ 713,2 Milhões

According LAZARD (2009), a technology that has the lowest cost level of electricity (\$ / MWh) is the wind power, followed by IGCC and last solar, which have their costs in the range of 113, 149 and 182 dollars respectively. Given this, which proves the attractiveness of electricity generation by wind power, but also shows that the IGCC technology has overall condition of a short-term economically viable.

Table 6 – Comparison between leveled electricity costs.

Technology Type	Leveled electricity cost (\$/MWh)
<b>IGCC</b>	US\$149
<b>Wind</b>	US\$113
<b>Solar</b>	US\$182

Even with an investment cost similar to that of wind and solar energy below the cost of maintenance and operation significantly increases the cost of an IGCC plant. Despite this fact, the cost of electricity in IGCC level proved to be less than the cost of solar energy. Wind energy can be sold for lower prices, as shown in Table 8. However IGCC technology is capable of generating electricity through coal are abundant and attend to environmental requirements.

With the reduction of operating costs or tax incentives in the future, IGCC technology may be included in the expansion plans of Brazilian thermoelectric sector, through the development of projects to generate electricity for long term.

#### 5 FINAL CONSIDERATIONS

Ability to generate electricity through coal, given current environmental requirements. However, no such technology proves to be viable, when compared with the generation of electricity through solar and wind energy, due to the fact there is a high cost of maintenance and operation.

Despite the advantages presented concerning the deployment of an IGCC plant, they have not yet settled on a large scale in the market, and its obstacles are the high cost of technology, lower reliability, long construction time and lack of operating experience.

In order to expand the use of this technology, it is necessary to integrate the capture of carbon that is collected prior to combustion, ie the combined cycle can be considered technically viable. Since the introduction of this technology on a large scale in the electricity sector depends on its economic viability, justified its higher return compared with the technologies of electricity generation.

Regarding the deployment of IGCC technology in Brazil, you can tell that this represents an interesting alternative for generating electricity, mainly in the south of the country, since the initiatives for the development of coal in Brazil in the area of thermal generation always consider the fact that the units are located near coal reserves, thereby reducing operating costs of the plants. Therefore, the logistics for the supply of coal is critical to the economic viability of IGCC projects.

2011.

## REFERENCES

- [1] DOLEZAL, R. **Kombinierte Gas-und Dampfkraftwerke**, 1st edition, Berlin Heidelberg, Springer-Verlag 2001.
- [2] **Electric Power Research Institute, Gaseification Technology Status**. United States of America 2005. Available at: <<http://my.epri.com/portal/server.pt?>> Accessed: 29 may. 2011.
- [3] HOFFMANN, Bettina Susanne. **O ciclo combinado com gaseificação integrada e captura de CO<sub>2</sub>: uma solução para mitigar as emissões de CO<sub>2</sub> em termelétricas a carvão em larga escala no curto prazo?** Dissertation Post Graduation in Energy Planning, COPPE. Rio de Janeiro, RJ. 2010.
- [4] **Lazard**. United States of America 2009. Available at: <<http://efile.mpsc.state.mi.us/efile/docs/15996/0145.pdf>> Accessed: 05 july. 2011.
- [5] MME, Ministério de Minas e Energia, e Empresa de Pesquisa Energética EPE. **Balanço Energético Nacional - ano base 2009**. Brasília, 2010.
- [6] National Renewable Energy Laboratory. **Innovations in wind and solar PV financing**. United States of America 2008. Available at: <<http://www.nrel.gov/docs/fy08osti/42919.pdf>> Accessed: 05 june. 2011.
- [7] ORTIZ, P. A. S. **Avaliação técnico-econômica de sistemas IGCC utilizando coque de petróleo e carvão mineral como combustível**. Dissertation Master in Mechanical Engineering. Federal University of Itajubá. in 2011. 141 p.. Available at: <<http://adm-net-a.unifei.edu.br/phl/pdf/0038056.pdf>> Accessed: 31 may. 2011.
- [8] REGO, E. E. **Avaliação da viabilidade de um empreendimento de geração de energia hidrelétrica**. São Paulo: University of São Paulo. 129 p. Monograph, Bachelor of Economic Sciences.
- [9] **EIA. U.S Energy Information Administration**. United States of America 2010. Available at: <[http://www.eia.gov/oiaf/beck\\_plantcosts/pdf/updatedplantcosts.pdf](http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf)> Accessed: 29 may. 2011.
- [10] **World Coal Association**. Available at: <[http://thefraserdomain.typepad.com/energy/2005/09/about\\_igcc\\_powe.html](http://thefraserdomain.typepad.com/energy/2005/09/about_igcc_powe.html)>. Accessed: 1 june.