Air Pollutant Control Strategies for Thermal Power Plants in KEPCO

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ABSTRACT

To meet the new stringent emission standards effectuated from Jan. 1999 for thermal power plants in Korea, KEPCO has implemented several proactive environment protection programs including reduction of sulfur dioxide(SO_2), nitrogen oxides(NOx), dust, and carbon dioxide(CO_2). As the major two actions to reduce sulfur dioxide emitted from thermal power plants, one is switching or substitution of cleaner fuel such as LNG and low sulfur fuel and the other is the installation of wet FGD systems. By 2001, 29 units of FGD system will be commissioned for thermal power plants in KEPCO. To reduce NOx emission, KEPCO has also adopted low NOx burner for new power plants. In addition, De-NOx systems(e.g. SNCR, SCR) are being installed for two power plants respectively. KEPCO also make plans for reducing the carbon dioxide by increasing the capacity of lower carbon emission type power sources(e.g. nuclear, LNG C/C, hydro-power, wind power, etc.), by improving thermal efficiency of power plants, by introducing high efficient and advanced power generation technologies such as IGCC, PFBC, and by increasing the new and renewable energies such as wind power, etc. These actions are expected to be effective environment preservation of electric power industry in Korea. In the 2000s, KEPCO will achieve the world-class environment-friendly corporation.

1. Introduction

Environmental considerations will be restraining factor with using fossil fuel in thermal power plants. Especially, air quality and global warming problem are hot issues in the world. In Korea, new stringent emission standard for thermal power plants set up and was in force from Jan. 1, 1999. Accordingly, KEPCO concentrate every effort on reinforcing emission control policies for thermal power plants to meet the new emission standards. Recently, for several years, various emission control facilities and technologies have been adopted to cope with new situation related to atmospheric environment. The purpose of this paper is to summarize various strategies of KEPCO to minimize air pollutants emitted from thermal power plants.

2. History of Environmental Laws in Korea

In Korea, environmental problems emerged in the 1960s when the country began to pursue full-scale industrialization with the launch of the first Five-year Economic Development Plan. To address environmental problems arising from industrialization, the Pollution Prevention Act was enacted in 1963, which is regarded as the first

environmental law in Korea.

As the country continued to attain rapid economic development, public concerns about environmental pollution had been heightened. In response, the Pollution Prevention Act was replaced with the Environmental Preservation Act in Dec. 1977 with the objective of environmental pollution prevention. To this end, the Government also introduced new systems to help cope with environmental problems more actively and comprehensively, such as the environmental impact assessment, environmental standards, and restrictions on the total volume of pollutants. The Environmental Preservation Act which had been enacted in 1977 was separated into six independent laws on Aug. 1990 ; the Basic Environmental Policy Act, the Air Quality Preservation Act, the Water Quality Preservation Act, and the Noise and Vibration Control Act etc. A number of subdivided environmental laws were enacted more recently to prevent damage to human health and the environment such as soil, drinking water, underground spaces, etc. As of Jun. 1999, there are 30 environmental laws under the jurisdiction of the Ministry of Environment.

3. Key Points of Air Quality Preservation Act of Korea

The Air Quality Preservation Act was enacted to help prevent damage to human health and the environment due to air pollution. To this end, the laws set specific emission standards for pollutant emissions from facilities, as well as impose charges for the pollutants that are discharged. These laws are most closely related to the environmental problems that are felt by the general public.

Permissible Emission Standards

The permissible emission standards of air pollutants emitted from facilities, which discharge pollutant, are determined by the Ordinance of the Ministry of Environment. Environmental SO_2 emission standard in Korea has become more stringent. As you can see on Table 1, in 1999, coal fired power plants have to observe the SO_2 emission level of 120-270ppm and NOx emission level of 350ppm, and oil fired power plants have to observe the SO_2 emission level of 120-180ppm and NOx emission level of 250ppm. This is why high efficient FGD or low NOx BNR is required for most of thermal power plants in Korea. But, some power plants using low sulfur fuel by below 0.3% or LSWR are exceptional and no need FGD system. Table 1 shows permissible emission standards for thermal power plants.

Emission Dues

In order to prevent or reduce the damages due to the air pollutants, the Minister of Environment impose and collect the emission dues on and from those businessmen emitting the air pollutants. Emission dues to impose for the emission of pollutants are classified as basic emission dues and excess emission dues. The basic emission dues is the amount imposed according to the quantity of pollutants emitted below the permissible emission standards in the workplace of any businessman who produces air pollution substances. The air pollutants to be imposed basic emission dues are sulfur dioxide and dust at present. This Concept is on the basis of Polluter Pay Principle(PPP). In the case of SO_2, basic emission dues is about US$420/ton-$SO_2$.

Table 1. New Permissible Emission Standards for Thermal Power Plants

Item			New Emission Standards	Remarks
SOx (ppm)	Coal	Existing plant	150.270(6)	Depending on plant
		New plant	120(6)	
	Oil	Existing plant	150.180(4)	Depending on plant
		New plant	120(6)	
NOx (ppm)	Coal		350(6)	
	Oil	Diesel Engine	950(6)	
		Others	250(4)	
	Gas	Diesel Engine	500(13)	
		Others	400	
Dust (mg/Nm3)	Coal		50(6)	
	Oil		40(4)	

Note : ( ) standard O_2

Restriction of Fuel Sulfur Content

The Minister of Environment may determine the permissible sulfur content for fuels.(see Table 2) With respect to the standards of fuel sulfur content, the Minister of Environment may determine the scope of supply area or its using facilities of such fuel under the conditions as prescribed by the Presidential Decree, and request the head of the central administrative agency concerned to supply those fuels needed to the areas or its using facilities.

Prohibition of Use of Solid Fuel

In order to prevent air pollution caused by the use of a particular fuel, the Minister of Environment or the relevant Mayor/Do Governor may restrict the use of solid fuels in the area where the environment standards are unlikely to be kept. Solid fuels include coal, coke, firewood and charcoal, combustible wastes(plastic refuse etc.)

Use of Clean Fuel

The Minister of Environment or the Mayor/Do Governor may prohibit the use of fuels except gaseous fuels such as LNG and LPG, etc., which produce little pollutants, to the facilities and areas that he publicly announces through consultation with the head of central administrative agency concerned as facilities and areas exceeding, or potentially capable of exceeding environmental standards. This regulation is applied to metropolitan and large city areas in Korea.

Table 2. Standards of Fuel Sulfur Content

Fuel		Before '96. 6. 30	'97. 7. 1.2001. 6. 30	after 2001. 7. 1
Oil	B-A B-B B-C	Below 1.0%	Below 0.5%* Below 1.0%*	below 0.3%* below 0.5%* below 1.0%*
	LO	Below 0.1%		
	LSWR	Below 0.3%		
Coal	Bituminous	Below 0.7%	Below 0.5%	below 0.3%
	Anthracite	Below 0.7%	Below 0.5%	below 0.5%

Note : * depending on region
The facilities with FGD are out of those standards.

4. Sulfur oxides Emission Control Strategies of KEPCO

Sulfur dioxide is one of major pollutant to be reduced for improving air quality in Korea. Table 3 shows the trend of SO_2 emissions from fossil fuel combustion, which has shown downward trend since 1992. This downward trend was caused by strict environmental policies as mentioned above. The shares of SO_2 emission of electric utilities have also been decreased since 1994. It accounted for about 16.5% of nationwide emission in 1998. KEPCO's strategies for SO_2 emission control are as followings.

Table 3. SO_2 Emissions of Nationwide and Electric Utilities by Year in Korea

		1990	1992	1994	1996	1998
Nationwide(1000 ton)		1,611	1,614	1,602	1,506	1,316
Electric utilities(1000 ton)		194	278	340	291	217
	Share (%)	12.0	17.2	21.2	19.4	16.5

Use of Low Sulfur Fuel

Korea is lack of energy resources except domestic anthracite coal which is small scale and low-grade, and of which consumption has been gradually decreased. So far coal has been regarded as major fuel source and almost of it has been imported from overseas such countries as Australia, Canada, China, Indonesia, etc. There are two options to supply coal. One is to supply very low sulfur coal to thermal power plants that have not FGD system. Otherwise coal contains sulfur content up to 1% is supplied to thermal power plants with FGD system. For oil fuel, it is controlled same as coal. Table 4 shows the trend of sulfur content of fuel used in KEPCO.

Table 4. Trend of Sulfur Content of Fuel Used in KEPCO

Fuel	1990	1992	1994	1996	1998
Coal	0.58	0.59	0.49	0.44	0.42
Oil	1.49	1.15	1.17	0.85	0.60

Operation of FGD

New stringent SO_2 emission standards led to construct FGD systems, thus as of June 1999, 20 units of FGD systems have already been commissioned and 9 units are under construction, which will be commissioned by 2001. Then total capacity of FGD systems will be reached 11,825MW.(see Table 5) We expected that about 65% of total SO_2 emission from thermal power plants could be reduced at that time. All of FGD systems are wet limestone gypsum process but types of absorber towers are different because of different manufacturer. So far these facilities have been operated without serious problems. All amount of by-product gypsum from FGD systems is utilized for manufacturing gypsum wallboard(about 92%) and cement(about 8%). The selling price of gypsum is about US$ 8/wet-ton at the basis of free on road. While, the purchase price of limestone is about US$ 20/ton at the received basis in 1998.

Table 5. Shares of Capacity of FGD Systems for Thermal Power Plants

Fuel Type		FGD (in 2001) Units	FGD (in 2001) Capacity (MW)	Capacity of thermal power plants (MW)	Share (%)
Coal-fired	Bituminous	18 units	9,000	13,800	65.2
	Anthracite	4 units	725	1,125	64.4
Oil-fired		7 units	2.100	4,486	46.8
Total		29 units	11,825	19,411	60.9

Notes : Total power generation capacity (2001) : 50,917(MW)
(Coal : 29.3%, Oil : 8.9%, Hydro : 7.6%, Nuclear : 26.9%, LNG : 27.3%)

Table 6. KEPCO's Construction Program of FGD Systems for Thermal Power Plants

Power plants	Unit NO.	Capacity (MW)	Fuel	FGD commissioning	License agreement	Absorber type
Youngdong	#1 #2	125 200	Anthracite	'98.12 '98. 3	KEPCO (Korea)	Tray
Seochon	#1 #2	200.2	-	'98.10 '98.12	-	-
Ulsan 3	#1, 2	200.2	B.C.	'99.8, '99.7	Bischoff (Germany)	Spray

Yosu 2	#1, 2	200, 300	-	'99.7, '99.5	Marsurex (U.S.A)	Spray
Poryong	#3, 4 #5, 6	500.4	Bituminous	'98. 9, '98.10 '99. 4, '99. 2	MHI (Japan)	Spray + Grid
Ulsan 1	#4, 5, 6	400.3	B.C.	'99.5, '99.6, '99.8	Chiyoda (Japan)	JBR
Taean	#1, 2 #3, 4	500.4	Bituminous	'98.10, '98.12 '99. 2, '99. 4	B&W (U.S.A)	Spray + tray
Hadong	#1, 2 #3, 4 #5, 6	500.6	-	'98.12, '99. 4 '99. 2, '99. 3 '00. 9, '01. 9	B&W (U.S.A)	Spray + tray
Dangjin	#1, 2 #3, 4	500.4	-	'99. 6, '99.12 '00. 9, '01. 6	Steinmueller (Germany)	Spray
Total	29units	11,825				

6. Nitrogen Oxides Control Strategies of KEPCO

Nitrogen oxides are also being considered one of major pollutants in respect of a precursor of acid rain and photochemical smog. NOx emission standard in Korea is relatively less stringent comparing with SO_2 and dust regulations. NOx emission from electric utilities has been going down since 1996, and its emission quantity was 153 thousand tons which was equivalent to 12.5% of total nationwide emission in 1998. (see Table 7)

Table 7. NOx Emissions of Nationwide and Electric Utilities by Year in Korea

		1990	1992	1994	1996	1998
Nationwide(1000 ton)		926	1,067	1,191	1,258	1,227
Electric utilities(1000 ton)		90	110	160	203	153
	Share (%)	9.7	10.3	13.4	16.1	12.5

NOx generation from thermal power plants is affected by various factors such as combustion temperature, configuration of furnace and burner, flame patterns, etc. Those sensitive factors make us difficult to select proper measures by each plant. Primarily, combustion control of boiler had been available for reducing NOx before starting installation of low NOx burner(Nox emission level less than 200ppm) from around 1995.

Table 8. NOx Technologies Applied to Thermal Power Plants in KEPCO

Type	Power Plants		Capacity (MW)	Fuel	NOx Reduction Methods					
					Low NOx BNR	Two stage combustion	GRF	Water Injection	Corner Firing	SCR or SNCR
Coal-fired	Seochon #1-2		200× 2	Anthacite + B-C						
	Yosu 1 #1-2		250× 2	Bitumino us						SNCR
	Samchonp o	#1-2	560× 2	"						
		#3-4	560× 2	"	LNCFS					
		#5-6	500× 2	"	PM					
	Poryong	#1-2	500× 2	"	Dual					
		#3-6	500× 4	"	PM					
	Taean #1-4		500× 4	"	PM					
	Hadong #1-4		500× 4	"	PM					
	Dangjin #1-2		500× 2	"	PM					
Oil-fired	Ulsan #1-2		200× 2	B-C			#1			
	Yosu 2 #1-2		200, 300	"					#1	
	Pyongtaek #1-4		350× 4	"						
LNG-fired	Seoul #4-5		137.5, 250	LNG		#4			#5	
	Inchon #3-4		325× 2	"						
Combined Cycle	Anyang		75× 4(G/T) 150× 1(S/T)	LNG	DLN					
	Pundang		75× 8(G/T) 185× 1(S/T) 115× 1(S/T)	"	DLN					
	Ilsan		100× 6(G/T) 200× 1(S/T) 100× 1(S/T)	"						
	Puchon		100× 3(G/T) 150× 1(S/T)	"						
	Seoinchon		150× 16(G/T) 75× 8(S/T) 150× 4(S/T)	"	DLN					
	Pyungtaek		80× 4(G/T) 160× 1(S/T)	"						
	Ulsan		100× 2(G/T) 100× 1(S/T) 150× 4(G/T) 150× 2(S/T)	LO						
	Hallim		35× 2(G/T) 35× 1(S/T)	"						
Internal combustion	Namcheju#1-4		10× 4	B-C						SCR
	Pukcheju#1-8		5× 8	"						

Recently, De-NOx systems, which are flue gas treatment systems, are under construction for two plants. One is SNCR process at Yosu 1 station, the other is SCR process at Namcheju station. KEPCO is planning to extend post flue gas treatment system like SCR for not only new power plants but also existing plants according to regulation to be stringent in early 2000.

7. Carbon Dioxide Control Strategies of KEPCO

The Korean Government has been undertaking various measures to promote the rational use of energy and has put comprehensive efforts to reduce greenhouse gas emissions. Particularly, the Government has been focusing on energy conservation policies as the most effective measures to mitigate greenhouse gas emissions.
Table 9 shows the projection of CO_2 emissions in energy sector. The projected CO_2 emissions in energy sector exhibits from 101.2 million TC in 1995 to 217.0 million TC in 2020. The annual average growth rate of CO_2 emission between 1996 and 2010 is projected to be about 5.2%. Per capita electricity consumption level in Korea is relatively low compared with major developed countries. As Korean economy grows, it is highly expected to follow the patterns of these developed countries in every respect, including life style, the advanced industrial structure, and so on, which requires more clean energy consumption like electricity particularly.

Table 9. CO_2 Emission Projection in Korea

	1985	1990	1995	2000	2005	2010	AAGR(%)	
							86-95	96-10
CO_2 emissions(million TC)	44.0	65.2	101.2	148.5	187.4	217.0	8.7	5.2
Per capita CO_2 emissions(TC)	1.1	1.5	2.3	3.2	3.9	4.4	7.7	4.5

Source : National Communication of the Republic of Korea(1998)

Table 10. CO_2 Emissions of Electric Power Sector in Energy Sector in Korea

		1990	1992	1994	1996	1998
Energy sector (million TC)		65.2	77.9	106.0	111.3	101.8
Electric power sector (.)		10.4	13.8	21.1	24.8	23.9
	Share(%)	15.9	17.7	19.9	22.3	23.5

The mitigation of CO_2 emission in electric power sector is important in Korea, as the share of electricity in energy sector is very high. In this sense, KEPCO have set the long-term stabilization goal for CO_2 emission at the level of 0.11kg-C/kWh. To achieve this goal, KEPCO is taking various measures to control CO_2 emissions from power plants as followings

Table 11. Comparison of International CO_2 Emissions

	Korea	USA	Japan	Germany	Italy	Canada
CO_2 emission share in electricity(%)	22.3	35.8	27.7	31.1	31.7	20.3
CO_2 emission per unit Generation(kg-C/kWh)	0.12	0.16	0.10	0.16	0.14	0.05
Nuclear generation(%)	36.0	20.1	29.9	29.4	-	16.0

Source : Energy Balances of OECD Countries (1995.1996)

Increase of Low CO_2 Emission Power Plants

KEPCO considers to increase the portion of low CO_2 emission power sources(nuclear power plants, LNG fired advanced C/C plants, Hydro & Pumped storage, etc.) as a major alternative to restrain the growth of CO_2 emissions in the situation of Korea. For the expansion of nuclear power plants, 16 new plants will be added to the existing 12 nuclear power plants by 2015. To restrain CO_2 emissions from thermal power plants, LNG-fired combined cycle is one of the significant strategies in KEPCO. Recently, we have installed LNG C/C plants very actively, particularly in metropolitan areas, to make up for the shortfall of the power and to reduce air pollutants. LNG C/C plants will continue to play there major roles because of not only CO_2 reduction but also high efficiency and unique operation characteristics. The share of generation capacity of low CO_2 emission power sources will be increased from 62.6% in 1998 to 67.3% in 2015, this figure is relatively high comparing with most of other developed countries.

Table 12. Outlook for the 4th Long-term Power Development Plan

Type		Generation capacity(%)		Power generation(%)	
		1998	2015	1998	2015
	Coal	26.0	26.8	2015	35.3
	Oil	11.4	5.9	9.6	5.8
low CO_2 emission	Nuclear	27.5	34.2	40.1	46.3
	LNG	27.9	24.5	11.6	11.5
	Hydro	7.2	8.6	2.9	1.1
	Sub. Total	62.6	67.3	54.6	58.9
Total		100	100	100	100

Improvement of Thermal Efficiency

Thermal power generations are directly related to CO_2 emissions. So, the improvement of thermal efficiency offers best opportunities for controlling CO_2 emissions with least cost. In this sense, to improve thermal efficiency, KEPCO adopted the measures as followings.

- increasing capacity per unit for new power plants
- application of super-critical or ultra super-critical boiler for new power plants

- expanding high efficient gas-fired combined cycle units
- reducing auxiliary power in the power plants
- introducing advanced power generation technologies such as IGCC, PFBC, etc.
  - KEPCO is planning to construct two high efficient and advanced power plants(IGCC or PFBC) in 2005 and 2012 each.

Table 13. Thermal Efficiency of Fossil Fuel-fired Power Plants

	1990	1992	1994	1996	1998
Thermal efficiency(%)	37.0	36.7	38.2	38.4	39.5

Reduction of the Transmission and Distribution Loss

We have made power loop carrying extra or ultra high voltage for reducing T&D loss, which result in mitigating the CO_2 emission due to the decrease of fossil fuel consumption at thermal power plants. Table 14 shows the status on transmission lines and T&D(Transmission & Distribution) losses by year in KEPCO. The losses of transmission and distribution will be reduced by the following measures.

- extension of high voltage transmission lines(345kV or 765kV)
- introduction of High voltage DC(HVDC) and Flexible AC Transmission sys.(FACTs)

Table 14. Transmission Lines and T&D Losses in KEPCO

Item		1990	1992	1994	1996	1998
Transmission lines(c-.)	765kV	-	-	-	-	54
	345kV	4,935	5,259	5,762	6,259	6491
	154kV	9,831	11,631	12,485	14,181	15,821
	under 66kV	4,130	3,579	3,370	2,705	2,551
	Total	18,896	20,469	21,617	23,142	24,917
T&D loss(%)	Transmission	3.24	3.36	3.16	3.27	3.22
	Distribution	2.38	2.42	2.43	2.13	1.68
	Total	5.62	5.78	5.59	5.40	4.90

Note : ultra(765kV), Extra(154-345kV), high voltage(under 66kV)

Reinforcement of Demand Side Management(DSM)

Demand side management(DSM) is also a possible option to reduce CO_2 emissions in power generation sector by slowing down the electricity demand itself. There are various programs in DSM from price control at peak time as incentive system to encourage energy conservation. Thus KEPCO is planning to save generation capacity from 470MW in 1997 to 6,460MW in 2015.(see Table 15) To do this, the investment for demand side management is expected to be required about 1% of electricity sales profits. Major actions are as followings.

- intensive public awareness campaigns for energy conservation to deter a peak power demand during the summer season
- electricity charge rate incentives for load management
- promoting the use of heat and cool storage equipment
- subsidies for high efficient energy equipment

Table 15. Yearly Target of Demand Side Management

Year	Demand side Management(MW)	Efficiency Improvement(MW)	Total
1998	470	10	480
2000	890	50	940
2005	2,620	330	2,950
2010	4,640	570	5,210
2015	5,730	730	6,460

Source : the 4th long-term power development plan in Korea(1998)

Development of New and Renewable Energy

In Korea, the share of new & renewable energy was not exceeded 0.8% in 1997. The Government amended the relevant law to widely utilize and motivate new & renewable energy sources in December 1997. Currently, the installed capacity of new & renewable energy capacity is 5,165kW.(see Table 16)

According to the 4th long-term generation plan established in 1998, because wind power was considered to be relatively superior to other renewable energy sources, it was adopted as a potential energy source. KEPCO will continuously make an effort to develop the technology for expanding renewable energy use.(see Table 17)
KEPCO has invested US$ 22 million in 41 R&D projects in order to develop new & renewable energy. According to the KEPCO's electric power technology development plan, KEPCO will invest about US$170 million in 4 areas of new & renewable energy by 2010.(se Table 18)

8. Conclusions

Fossil fuel as an energy source will continue to play a major role to meet energy demands in the 21st century. However, a variety of environmental restrictions will become a determinant for the energy policies in the electric power sector. As state-owned electric power corporation, KEPCO will take part in global efforts for reducing greenhouse gas and lead the development of environment-friendly power sources. KEPCO also plans to gradually expand the low emission energy sources and to develop the promising technologies with a future focus. Conclusively, to cope wisely with the situations and challenges in the upcoming 21st century, KEPCO will do his best to become a world-class electric power corporation in terms of global environment preservation.

Table 16. New & Renewable Energy Sources for Electric Power in Operation in Korea

Area	Owner	Capacity(kW)	Location
Solar Cell (490kW)	KEPCO	120	Hodo, Chungnam : 90kW Marado, Cheju : 30kW
	Government	167	Hahwado, Chonnam : 60kW Others : 107kW (9 places)
	Private	203	Samsung Institute : 100kW Others : 103kW(14 places)
Wind Power (4,275kW)	Cheju Province	2,745	Hangwon, Cheju
	KIER	160	Wollryung, Cheju(for research)
	Korea Fiber Co.	1,050	Muan, Chonnam(for research)
	Korea Tourism Co.	250	Jungmun, Cheju(for tourism)
	Others	70	Wollryung & Marado, Cheju (for research)
Fuel cell (400kW)	Korea Gas Co.	200	Ansan, Kyonggi(for research)
	Hyundai Heavy Industry Co.	200	Ulsan(for research)
	Total	5,165	-

Table 17. New & Renewable Energy Development Plan

Plant NO.	Type	Completion	Capacity(kW)	Site
#1	Wind/Solar	2002	5,000	Cheju
#2.4	"	2003.2005	5,000	Undecided
#5.9	"	2006.2010	20,000	"
Total			30,000	

Table 18. KEPCO's Electric Power Technology Development Plan (1998.2010)

Type	R&D cost (millionUS$)	Target of technology development
Solar Cell	16.3	▵ Development of 50kW class plant (1999) ▵ Utilization technologies for small & medium class plants (2002) ▵ Development & utilization of MW class plant (2006)
Wind Power	3.6	▵ Operation technologies for medium class plant (1999) ▵ Operation & construction technologies for MW class plant (2005) ▵ Construction technologies of large scale complex (2008)
Molten carbonate fuel cell	71.2	▵ Development of 25kW class plant (1999) ▵ Development of 100kW class plant (2002) ▵ Operation & evaluation technologies of 250kW class plant (2008)
IGCC	80.8	▵ Detail technologies evaluation of 300MW class of IGCC (1999) ▵ Design & operation technologies of 300MW class of IGCC (2007) ▵ Design technique of 600.800MW class advanced IGCC (2009)