"PIEMSA IGCC Project Environmental and Economical Benefits"

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ABSTRACT

PIEMSA, an affiliated company of Petronor, one of the companies of the Repsol YPF group, are planning to build an IGCC complex adjacent to the Petronor Refinery in Bilbao area, in the Basque region of Spain.
The IGCC complex will process refinery heavy stocks to produce electric power and hydrogen to be used in the Refinery for hydrogenation purposes. The expected capacity will make this plant the biggest power plant of this type ever conceived. Detailed studies have demonstrated the viability of the project. In this paper an indication of the reasons why Petronor decided to implement this project, a description of the project, the environmental and economical benefits for the refinery and for the Basque region will be illustrated.

1. INTRODUCTION

Presently Petronor runs a refinery (see attached picture nb. 1.1)
with an operating configuration oriented to the production of gasolines and diesel oils with a certain amount of residual fuel oil; the average fuel oil production accounts for 25 % of the overall refinery production. The quality and quantity of fuel oil produced is heavily dependent from the quality of crude processed.

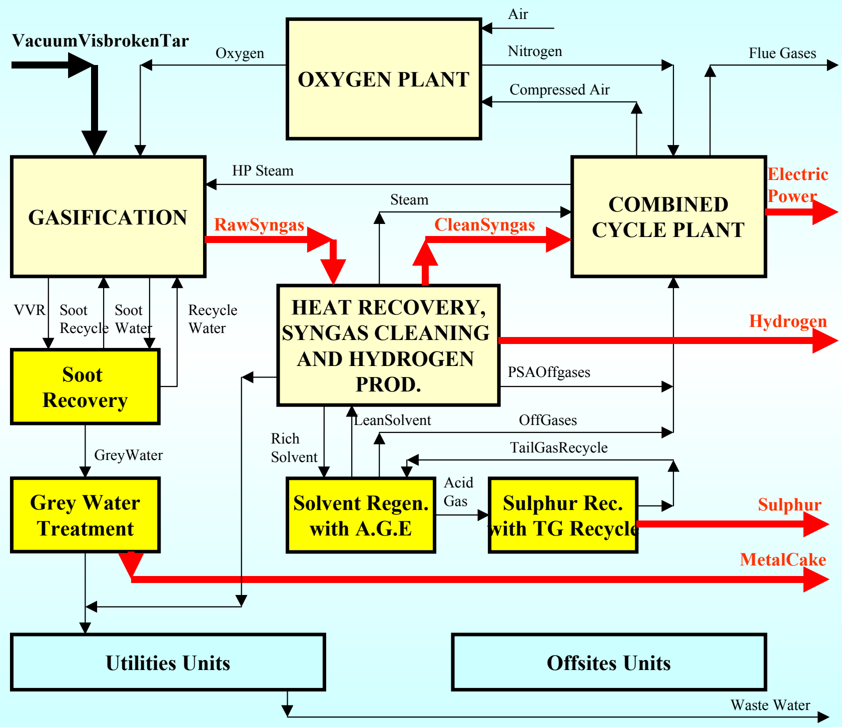
Picture 1.1 – Petronor Refinery in Bilbao area, Spain

Nowadays the fuel oil production is partially used to sustain the combustion in the refinery furnaces and mostly sold to the market mainly for ships bunkering and combustion in power stations.
The environmental constraints and the request to have more efficient power stations (natural gas combined cycles are preferred versus conventional fuel oil power stations) cause the shrinking of the fuel oil market available to the Refinery.
Additionally cheaper crude oils are normally the heaviest with the highest sulphur content. The processing of cheaper crude oils increases the fuel oil production in the Refinery production scheme.
More, it has been recognized on the international market an irreversible trend for crude oils to become heavier.
It became an urgent strategical problem for the Refinery to find alternative routes to dispose the fuel oil production.
Several options were available and the one that better fitted the requirements was the IGCC with the aim to dispose almost all fuel oil in spite of quality variation of crude oils processed, and produce electric power instead of selling fuel oil to thermal power station.
The capability of the IGCC to convert all fuel produced in the refinery, in spite of the quality, into electric power, makes available to the refinery all products that were used to flush the oil to make it compatible with the market specification, i.e. viscosity and sulphur content. The products used for flushing are distillates like gasoil that become available for the market with higher selling prices for refinery balance benefit.
The IGCC solution is globally environmentally beneficial, in fact the control of the combustion emissions is more efficient in an IGCC than in an existing conventional thermal power station.
Additionally it is possible to compare a combined cycle of new generation as available on the market today burning LNG and find that from the economical point of view the CCU and the IGCC become comparable when the dynamics of fuel prices are favourable as they are today.

2. IGCC COMPLEX DESCRIPTION

The heavy oil Integrated Gasification Combined Cycle (IGCC) Complex is a multi unit complex, designed to process the high sulfur by-products of the adjacent Petronor Refinery and produce electric energy and hydrogen. The electric energy will be delivered to the distribution grid while hydrogen will be returned to the Petronor Refinery to upgrade refinery products.
Additional products of the IGCC Complex are sulphur and metal concentrate; both these products are saleable. The description of the IGCC reported below should be read in conjunction with the attached block flow diagram of the Complex (fig. 2.1)

Figure nb.2.1 - IGCC Complex Overall Block Diagram



PROCESS UNITS

The Process Units of the IGCC Complex are designed to process 195 t/h of Visbroken Vacuum Residue.

<u>Gasification related Units</u>

The Gasification Unit is based on two trains, operating in parallel including two Texaco quench type gasifiers; the gasification reaction is conducted with oxygen, in presence of steam as temperature moderator.
High pressure gasification reactors have been selected (64 barg). Syngas produced is quenched with water inside the gasifiers and then routed to a scrubbing tower, adequately sized to remove solid particles originated by unreacted carbon, ashes and metals present in the feedstock.
The syngas components are H_2, CO, CO_2, H_2O, H_2S, COS, CH_4, and Ar/N_2.
The black water from the bottom of gasifiers is sent to the treatment for the recovery of unreacted carbon and elimination of ashes and metals.

The first step of black water treatment is the soot extraction where unreacted carbon is extracted and recycled back to the gasification reactors.
After carbon recovery, most of the water (grey water) is recirculated to the syngas scrubber as scrubbing water, while the rest of grey water is delivered to the chemical treatment for metals recovery.

Syngas Conditioning Units

The raw syngas from the scrubbing section of the gasification unit is processed in the syngas cooling and conditioning units, to purify the syngas to be fed to the combined cycle.
The raw syngas cooling is achieved recovering heat to produce steam and preheating the condensate stream to the HRSG's in the combined cycle section of the IGCC.
The condensate, separated from the raw syngas during the cooling process, is returned back to the gasification as scrubbing water.
The purification consists of the selective sulfur removal by means of a MDEA solution. The absorption reaction takes place at ambient temperature and is limited to H_2S with a minor quantity of CO_2. The syngas, before MDEA absorption, is passed through a hydrolysis reactor to convert the COS into H_2S.
A small part of clean syngas is then processed through membranes to recover hydrogen, and the permeated hydrogen rich gas is sent to a Pressure Swing Absorption unit for hydrogen purification. The hydrogen produced at a pressure of 21 barg and with a purity of 99.8% is sent to the Refinery.
The clean syngas, after partial H_2 separation, at high pressure is ready to be fed to the Power Island, but to improve the energy recovery it is expanded down to the minimum pressure required by the gas turbine and then preheated up to 135°C using available waste heat.

Sulphur Recovery Units

The MDEA rich solution coming from the absorption tower is flashed, raised in temperature and stripped in a regeneration tower to free the contained H_2S and CO_2. The lean MDEA before starting again the absorption step is cooled down to ambient temperature and partially treated to remove the heat stable salts that are not regenerated in the stripping tower. The accumulation of heat stable salts (namely oxalates, tyocianites, formiates, etc...) must be avoided because they reduce the MDEA solution activity.
The H_2S rich stream from the MDEA Regenerator flows to the Acid Gas Enrichment Section. This section utilizes a special amine solvent, suitable to capture, at low pressure, the H_2S selectively, with minimum absorption of CO_2.
The H_2S rich stream coming from the MDEA Regenerator is scrubbed, with this solvent, in the enrichment absorber; the emerging CO_2 rich gas stream goes to postcombustion in the Heat Recovery Steam Generators, while the amine rich solution is regenerated in a stripping tower delivering acid gas, with high H_2S concentration (approx. 70% conc.), to the Claus Unit , and lean solvent solution recycled back to the enrichment absorber.
The enrichment absorber also treats the Claus tail gas, after hydrogenation and recompression.

In the sulfur recovery unit the H_2S rich stream is burned in the presence of oxygen in a muffle furnace followed by two reactors in series where the Claus reaction takes place to produce liquid sulfur.

Air Separation Units (Oxygen Plants)

The oxygen required both for the gasification reaction and the Claus reaction is produced in the Oxygen Plant where air is fractionated by cryogenic distillation.
The Oxygen Plant is partially integrated with the Power Island. In fact a portion of the compressed air (30%) required by the Oxygen Plant is delivered directly from the gas turbine compressors.
Nitrogen is also coproduced in the oxygen plant in both a gaseous and liquid form; gaseous nitrogen is compressed to feed the gas turbine to reduce NOx emissions and increase power output. Liquid nitrogen is produced to constitute a holdup to be used for emergency purging of the gasifiers and for back up of LP nitrogen distribution.

POWER ISLAND

The clean syngas produced in the gasification section and syngas treatment is fed to the Power Island.
Two gas turbines followed by two heat recovery steam generators and one steam turbine have been provided to convert syngas thermal power to electric energy.
The gas turbines burn almost all the syngas produced; a postcombustion system, foreseen in the heat recovery steam generators, burns the PSA off-gas coming from the Hydrogen Production and the treated gas produced by the Acid Gas Enrichment and excess (if any).
Nitrogen is used to dilute the syngas to obtain reduced NOx emission and to improve the gas turbines power output up to their maximum limit.
The Power Island is accurately integrated with the process units in order to increase the Complex overall efficiency; high pressure steam is exported mainly to the gasification reactor while the recovered low pressure steam is processed in the combined cycle.
The gas turbines can also operate with natural gas when syngas production is down and for startup purposes, and even in cofiring mode (syngas plus natural gas) in case of syngas shortage.

UTILITIES AND OFFSITES UNITS

Several service units are foreseen to operate the Complex.
Cooling water for use in the steam turbine condenser and for Oxygen Plant users is once through sea water pumped from a sea water intake installed in the Refinery harbour. The return to the sea is located out of the Refinery harbour paying attention to avoid interference between the discharge and the sea water intake.
Circulating conditioned sweet water, cooled by sea water, is used as cooling stream for machinery cooling and process users.
Demineralized water system, condensate recovery system, plant and instruments air system, auxiliary fuels systems and firefighting are the other utilities units.

The IGCC Complex includes also a flare system to dispose hazardous gases during emergencies and misoperations.

Other major auxiliary systems of the Complex are:

- liquid sulphur solidification and storage;
- metal cake handling and storage;
- electrical distribution;
- step-up transformers and connections to the grid.

3. MATERIAL AND ENVIRONMENTAL BALANCE

In order to appreciate the advantages to have an IGCC within the Refinery processing units it is important to verify how with the same amount of crude oil processed the products slate changes and how the overall emissions to atmosphere are improved. The attached table 3.1 should be reviewed.

Table nb.3.1 - Overall products and electric power production balance

		As today			**After IGCC installation**		**net balance**	
		Material Balance			Material Balance			
Refinery								
Imported Crude Oil		**8,000,000**	t/y		**8,000,000**	t/y	**----------**	t/y
Ligth Products		**6,000,000**	t/y		**6,500,000**	t/y	**500,000**	t/y
Heavy Oils	(3% S)	**2,000,000**	t/y	(x% S)	**1,500,000**	t/y		
IGCC								
Heavy Oils		--------------			**1,500,000**	t/y		
Electric Power (2)		--------------			**6,280,000**	MWh/y		
Sulphur		--------------			**80,000**	t/y	**80,000**	t/y
Ex.Thermal Power Stations								
Heavy Oils	(3% S)	**1,585,000**	t/y		-------------			
Electric Power (1)		**6,280,000**	MWh/y		-------------			
National Market								
Heavy Oils(fuel) (3)	(3% S)	**415,000**	t/y					
		Environmental Balance			Environmental Balance			
Emissions								
SO2		**7,350**	t/y		**2,770**	t/y	**-4580**	t/y
NOx		**8,270**	t/y		**4,670**	t/y	**-3600**	t/y
Part.		**950**	t/y		**630**	t/y	**-320**	t/y
Calcium Sulphates (solids)		**207,000**	t/y		**---------**	t/y	**-207,000**	t/y

Notes: (1) based on 8000 hours a year with a net hourly production of 785 MW in existing fuel oil thermal power station with a net efficiency equal to 37 % with fuel oil @ 9200 kcal/kg (LHV)

(2) based on 8000 hours a year with a net hourly production of 785 MW in the IGCC power station with efficiency equal to 41% with fuel oil @ 8800 kcal/kg (LHV)

(3) sulphur disposal unknown (normally heavy fuel oils are used for ships bunkering)

From the table the same amount of crude oil processed (8,000,000 t/y) is converted in the

refinery into light products and fuel oil; while withouth IGCC the fuel oil is produced on spec., with the IGCC no care is given to the fuel oil specification.
The presence of the IGCC allows an extra production of 500,000 t/y of distillates to be made available for the market and 1,500,000 t/y of fuel oil are processed in the IGCC producing 6,280,000 MWh per year with sulphur as valuable byproduct.
Without IGCC, as nowadays, the fuel oil production is partially sold to conventional thermal power stations (capable to produce electric power as the IGCC for comparison purposes) and partially distributed to the market (typically for ships bunkering).
With the same crude oil input to the Country, 500,000 t/y of distillates more are made available while maintaining the same electric power production and with a sacrifice in fuel oil production for ships bunkering.
As far as environmental impact, the numbers reported in table nb.3.1 show a substantial benefit expressed in lower quantities of contaminants and without the tediuos production of sulphates from the flue gases desulphurisation processes.
The comparison with thermal power station that do not adopt the desulphurization process is not proposed even if several existing power station are not fitted with desulphurisation processes.
The attached table nb.3.2 shows a detailed atmospheric emission comparison between a thermal power station burning 3% fuel oil with desulphurization process incorporated in line with regulations and an IGCC where the feedstock contains 5.5% sulphur. All quantitative figures make reference to a power station having the same net power output.
IGCC techonology is by far the most enviromental friendly technology available for power production, no matter is the amount of contaminants available in the fuel.

Table 3.2 - Emissions from an existing Thermal Power station burning fuel oil and an IGCC having the same net electric power production capacity (785 MW)

Thermal Power Station		**IGCC (Integrated Gasification Combined Cycle)**	
Fuel Oil (3%S)		Fuel Oil (5.5%S)	
Gaseous Emissions according LCP Directive 88/609 1988		Gaseous Emissions guaranteed	
SOx (400mg/Nm3@3%O2dryv.)	**7350** t/y	**SOx** (45mg/Nm3@15%O2dryv.)	**2770** t/y
NOx (450mg/Nm3@3%O2dryv.)	**8270** t/y	**NOx** (75mg/Nm3@15%O2dryv.)	**4670** t/y
partic. (50mg/Nm3@3%O2dryv.)	**950** t/y	**partic.** (10mg/Nm3@15%O2dryv.)	**630** t/y
Solids to be disposed		Solids to be disposed	
CaSO4	**207,000** t/y	**none**	

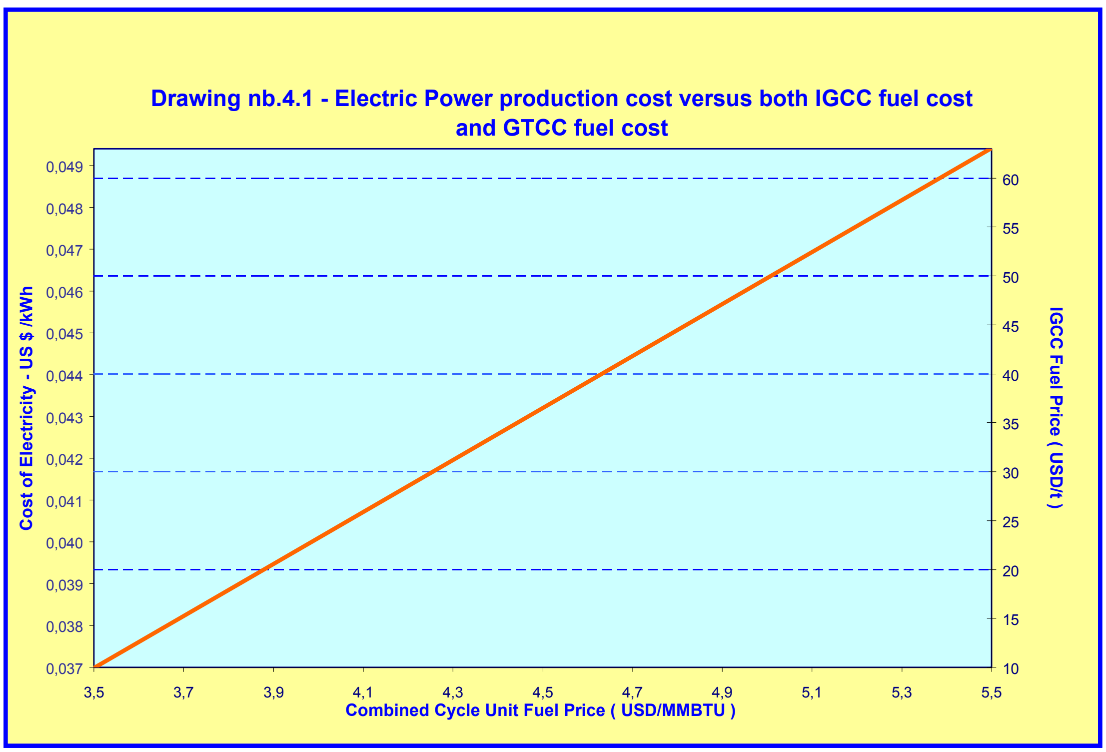
4. COMPARISON WITH GTCC

Today in Spain the most attractive technological solution to produce electric power is the Combined Cycle; with appropriate selection of gas turbines as prime movers it is possible to achieve efficiencies over 55%. The fuel adequate for Combined Cycle is natural gas and its use makes this kind of plant very appealing from the environmental point of view; additionally Combined Cycle are flexible from the operating point of view and easy to operate while their investment cost is limited per kW installed. However the use of natural gas as fuel makes these plants very vulnerable to the fuel market price variations. Natural gas price demonstrated in the past few months an impressive instability with unpredictable excursions in certain areas of the world.

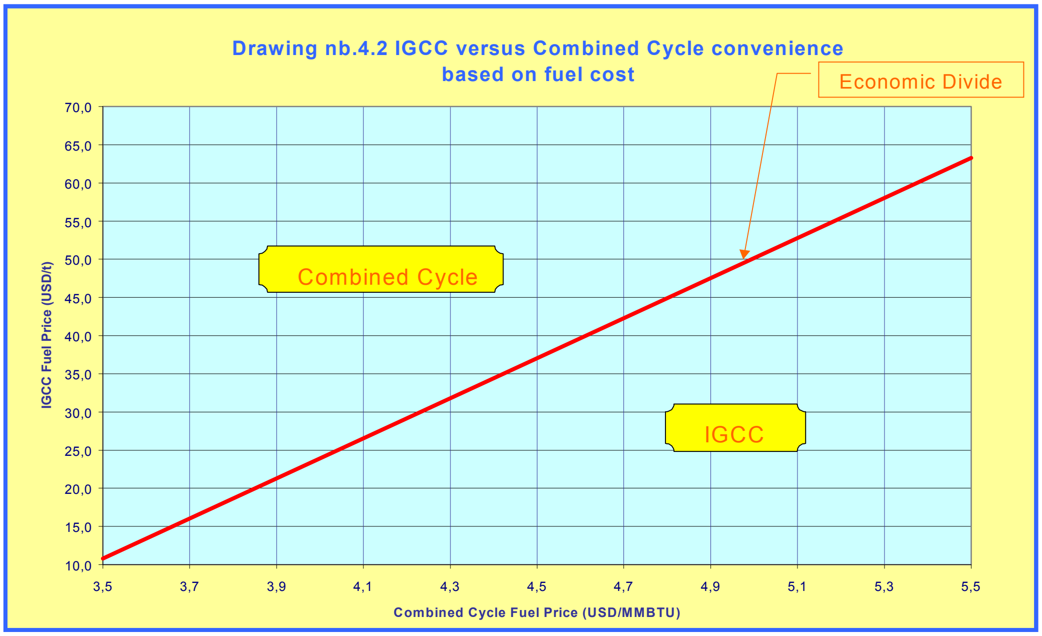
There are situations where an IGCC located nearby a refinery can demonstrate its superior economical performance; same evaluation have been done with the aim to find the breakeven point where to give preference to an IGCC versus a GTCC.

No consideration is given to the fact that the fuel oil market is shrinking.

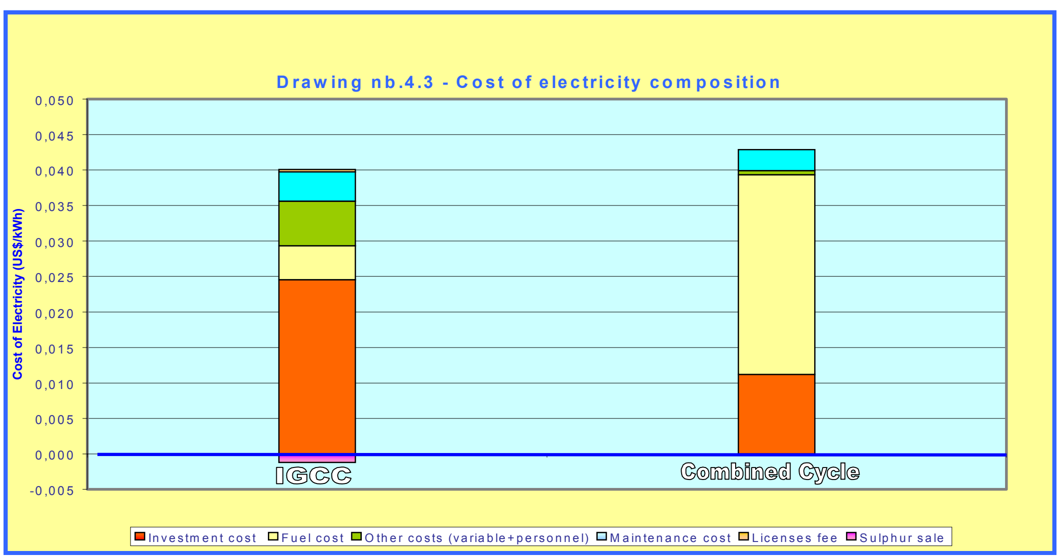
Dwg. nb.4.1 attached shows the expected cost of electricity versus the IGCC fuel cost and versus the GTCC fuel cost. The red line crossing the chart should be used as pivot; as an example, when the IGCC fuel cost is 30 US$ per ton., the same electric power production cost is achieved in a combined cycle when the natural gas cost is 4.25 US$ per MMBtu.



With the same information it is possible to prepare a drawing (nb.4.2) that quickly provide a perception when the IGCC should be considered more appealing than a GTCC.



It is important to focus our attention on how the electric power production cost is made up; the attached drawing nb. 4.3 shows the differences between the IGCC and the GTCC. It is possible to notice the impressive influence of the investment cost when the IGCC is considered versus the fuel cost for the GTCC; once the IGCC is built, considering that the heavy residues cost is approaching zero value, the investment cost for an IGCC is less exposed during its life to unpredictable events than a GTCC that always is subject to natural gas price variations.



5. ADDITIONAL CONSIDERATIONS

While the comparison performed and reported in paragraph 4. above, consider the IGCC and GTCC plants as stand alone, it is possible to benefit the IGCC of the improved revenues from the Refinery operation.
From table 3.1 it is possible to derive an extragasoil production of 500,000 t/y that account for a revenue of 150,000,000 US$ at an average selling price of 300 $/t for the light products.
The today fuel oil sale is giving to the Refinery an income of 100,000,000 US$ if valued 50 US$/t.
The improved income foreseen in the Refinery when the IGCC will be in operation is 50,000,000 US$ and this amount of money if accounted for the IGCC or if the IGCC is considered a Refinery Unit can give an additional reduction in the electric power production cost equal to 0,0072 $/kWh.
It appears that an integrated vision of the IGCC within the Refinery can give a boost to the project feasibility; it is authors opinion that this is one of the reasons why the IGCC on heavy oils have several chances to become an important solution for Refineries to exhaust the crude oils processed.
Additionally the past experience tell us that the Refineries are proner to consider the installation of a power station in their infrastructures; in fact one of the most important problem to solve is that in an IGCC it is necessary to combine three industrial worlds with completely different mentality and problem solving strategies:

- the clean gas production units;
- the chemical units;
- the power production units;

Refineries are a good environment to combine these worlds as demonstrated by the Italian IGCC installations.

6. REFERENCES

In the preparation of this paper reference is made to:

- "The 800 MW PIEMSA IGCC project" written by L. Bressan, T. Ubis and L. O' Keefe and presented to San Francisco 2000 Gasification Conference.
- "GE IGCC Information" – B. Jones, GE Power Systems.

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