

# ISAB ENERGY IGCC – NEW HYDROGEN PLANT

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## Introduction

The Integrated Gasification Combined Cycle (IGCC) plant of ISAB Energy in Sicily (Italy) has entered its 8<sup>th</sup> year of commercial operation. The plant includes two gasifiers based on GE technology and two Ansaldo-Siemens V94.2K gas turbines.

Foster Wheeler Italiana (FWI) assisted ISAB Energy in the realization of the project right from the early phases, carrying out the feasibility studies, basic design, FEED and cost estimate evaluation. Then FWI was awarded the EPC contract on a LSTK basis, in consortium with Snamprogetti.

ISAB Energy has recently decided to install new facilities for the production of 20,000 Nm<sup>3</sup>/h of hydrogen for the adjacent refinery. The plant configuration selected consists of the addition of a third gasification unit, smaller than the two existing ones, and a new hydrogen production unit including Membrane and PSA. The capacity of the new gasification unit, 18 t/h of asphalt, will assure the required hydrogen production and will allow a slight increase of the syngas production capacity which, in turn, will improve the overall power generation availability.

ISAB Energy has awarded to FWI the EPCM services contract for the installation of these new facilities. This choice has allowed the best synergy between the ISAB Energy and FWI experiences gained in the operation and maintenance (ISAB) and in the design and construction (FWI) of the existing plant. The project is currently under execution.

The paper presents some of the key technical and economical considerations that have been the basis of ISAB Energy's decision to proceed with the new investment.

The paper also describes the modifications required to be made to the IGCC Complex in order to make it capable of producing 20,000 Nm<sup>3</sup>/h of hydrogen. It also discusses the expected impact of the new installations on IGCC plant performance in terms of efficiency, power production, liquid and gaseous emissions, availability and reliability.

Finally the project execution plan is presented, reviewing the strategy adopted to ensure the construction and start-up of the new facilities in a safe and effective manner, while the existing plant is in operation.

## The decision to produce hydrogen from asphalt gasification

The ERG Refinery that supplies the asphalt feedstock to the ISAB Energy IGCC plant requires an additional quantity of hydrogen, 20,000 Nm<sup>3</sup>/h, to support the production of the Euro grade automotive fuels, which are being introduced as a result of more stringent European Union fuel quality and environmental legislation.

ERG had three options to make the required hydrogen available: (i) internal production by revamping certain refinery process units, (ii) purchase H<sub>2</sub> from an external gas supplier (iii) purchase H<sub>2</sub> from ISAB Energy (company owned by ERG group).

Since the process units that produce hydrogen inside the refinery had been already revamped in the last decade, the first option requires the installation of a new steam reformer fed by natural gas, making this alternative very similar, from an economic point of view, to the possible over-the-fence supply.

The third option (import from ISAB Energy) implies the addition of a third gasifier and new hydrogen production facilities (Membranes and PSA) inside the existing IGCC plant, in order to maintain the present electric power production (560 MWe). The original IGCC design included the production of 20,000 Nm<sup>3</sup>/h hydrogen achieved by separating hydrogen from the clean syngas containing approximately 40% vol. Due to the fixed/standard size of the two gasifiers, the use of syngas to produce hydrogen would have reduced the thermal input available to the combined cycle and, as a consequence, the IGCC power production. Economic reasons (a very high hydrogen cost calculated on the basis of the lost electric power) led to the decision not to install the hydrogen unit. However the combined cycle equipment (gas turbine and HRSG post-firing) were designed taking into account the possible future installation of this unit.

The comparison of the two options (i.e. hydrogen production from natural gas or from asphalt) was made by ERG, taking into account all the impacts on the whole complex, Refinery and IGCC. The decision was taken considering the capital and operating costs of these two alternatives, including the modifications to the refinery products asset. The economic analysis was made according to the economic/financial standards/criteria adopted by ERG for all of their strategic investment assessments. The reference is set in 2009, with a forecast of the all the economic/financial parameters over the next ten years. The capital cost and operating costs estimates related to the IGCC Hydrogen Production Project are based on the feasibility study made by FWI in early 2006.

As expected, the capital expenditure required for the IGCC Hydrogen Production Project is higher than that required for a Methane Steam Reformer. The difference is more than 10 Million Euro (+/- 20% accuracy).

The operating costs estimated by ERG for the two plants are split into fixed costs including mainly the investment cost return, O&M and insurances, and the variable costs.

For the Hydrogen Production Project the variable costs are relevant to the additional consumption of asphalt, oxygen, electric power, steam and other utilities, and to the additional CO<sub>2</sub> emissions related to the production of hydrogen.

For the steam reformer unit the variable costs include mainly the natural gas and the electric power, as well as associated CO<sub>2</sub> emissions.

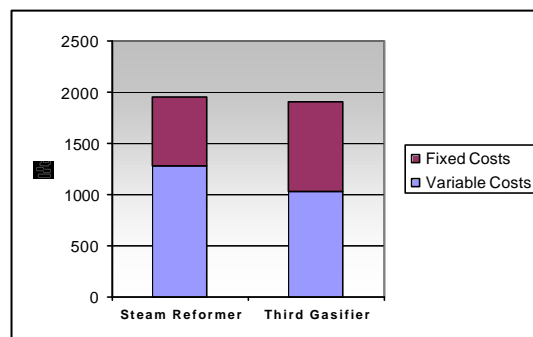


Figure 1 - 2009 H<sub>2</sub> Production costs for both alternative

As shown in the attached diagram (Figure 1), the fixed costs are higher for the gasification option (+30%), while variable costs (mainly methane vs asphalt) are lower (-20%). The combination results in a slightly lower hydrogen price for the gasification option (-2.2%) (1900 €/t, i.e. 0.17 €/Nm<sup>3</sup>). The difference becomes larger over the next ten years (Figure 2) with a hydrogen cost 10% lower for the gasification option in 2020.

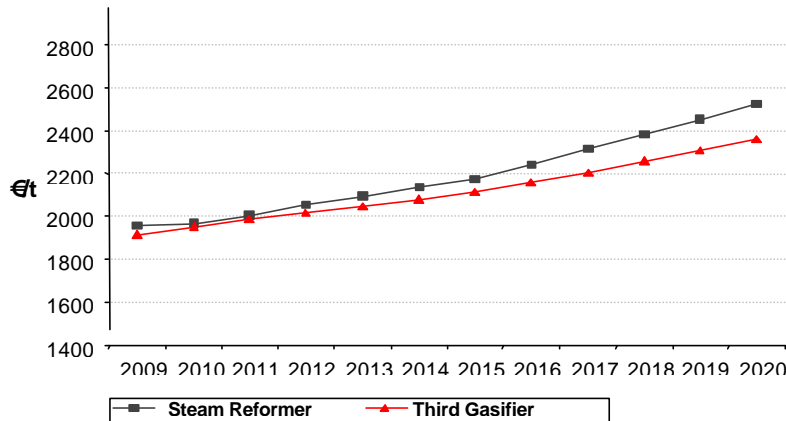


Figure 2 - H<sub>2</sub> Production Cost Forecast

As well as the economic comparison there are other effects of hydrogen production from asphalt that contributed to the final choice of this option. The main effect is related to the impact of a larger asphalt consumption, i.e.:

- a reduction of fuel oil production, beneficial in approaching the target of a zero fuel oil refinery;
- an increase of Deasphalted Oil (DAO) production. This stream is a suitable feedstock to the FCC unit, resulting in an increased quantity of valuable products like gasoline and gasoil at fixed crude oil processing.

The additional revenue is estimated to be some million Euros per year. Figure 3 shows a block flow diagram including the main units involved.

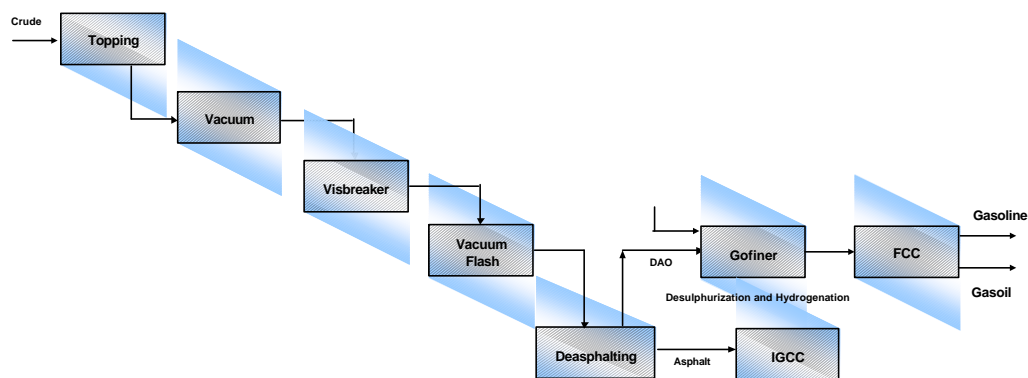
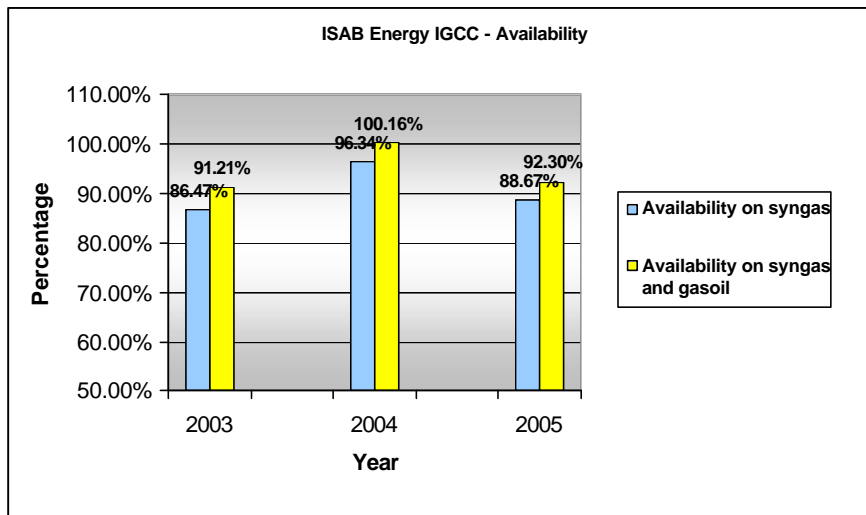


Figure 3 - Refinery Block Flow Diagram

Further, the third gasifier has operational and economic benefits for ISAB Energy related to the improvement of the overall IGCC power generation reliability/availability. This is due to its design capacity which is larger than the hydrogen production requirement (18 t/h asphalt vs 7.5 t/h), allowing a slight reduction of the main gasifiers' load during normal operation and partially compensating for the planned or unplanned shut-down of one of the existing gasifiers. The additional power production is estimated to be about 30,000 MWh per year, corresponding to a 0.7% increase of syngas equivalent availability. Figure 4 shows the trend of the IGCC availability in years 2003-2005 [1].

**Figure 4 - ISAB Energy IGCC - Availability**



From the combination of all these economical contributions, the IRR of the new Hydrogen Production Project is close to 15%, with a payback time of 5.5 years.

A sensitivity analysis on the investment cost was made showing the IRR at 13.9% with a +10% investment cost.

### The existing IGCC Plant

The main units of the plant are shown in the block flow diagram of Fig. 5. The feedstock to the gasification unit is asphalt, produced in a solvent de-asphalting unit, licensed by Kellogg, where de-asphalted oil, sent back to the Refinery, is also produced. The asphalt is an extremely heavy stock, with 6% S, about 1,000 ppm metals (Ni-V-Fe) and a softening point close to 120°C. The pumping temperature is expected to be maintained at 260–280°C.

Two quench-type GE gasifiers are used to convert 132 t/h asphalt to syngas by partial oxidation with pure oxygen and HP steam as asphalt atomizer and reaction moderator. The carbon soot is recycled to the gasifiers, except for a blow-down stream which is chemically treated to precipitate a metal concentrate cake, stripped with steam for ammonia release and finally biologically treated to reduce its oxygen demand.

The syngas emerging from the gasification unit at 240°C passes through a heat recovery section, generating MP and LP steam, then a COS catalytic hydrolysis and finally an

acid gas removal, using an activated amine solution (MDEA) to remove selectively H<sub>2</sub>S with minimum absorption of CO<sub>2</sub>.

The concentrated acid gas from the MDEA regenerator is converted to elemental sulfur in an oxygen Claus unit followed by a tail gas treatment. Treated syngas, after pressure reduction in an expander to recover energy, is humidified to a level of 35%, which allows a drastic cut in NO<sub>x</sub> produced in the gas turbine combustors.

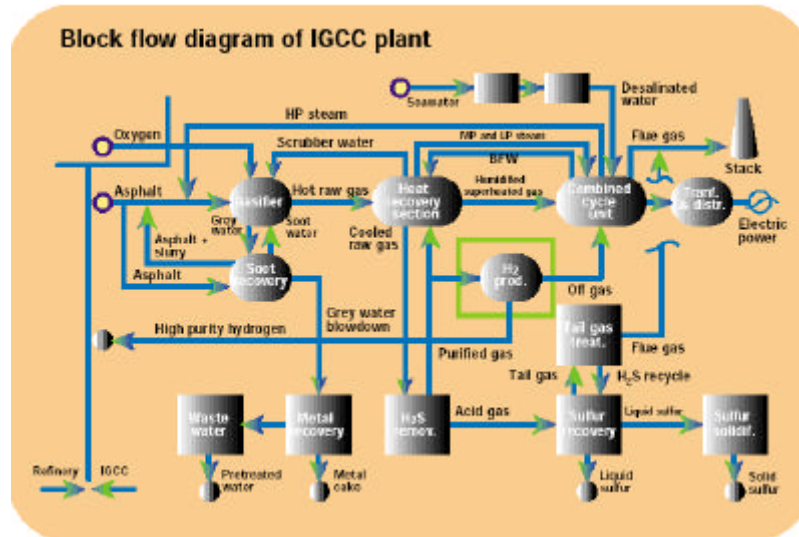


Figure 5 - Block Flow Diagram of existing IGCC plant

Treated and humidified syngas is fed to the gas turbines of the power block.

The power block consists of two trains, each including one gas turbine, Ansaldo/Siemens frame 94.2K, one heat recovery steam generator and one condensation steam turbine. HP steam is fed to the gasifiers, while the MP and LP steam produced in the process units is sent to the combined cycles for power recovery.



Figure 6 - ISAB IGCC plant

## The capacity of the new gasifier

In order to produce 20,000 Nm<sup>3</sup>/h of hydrogen and to maintain the present IGCC electric power output of 560 MWe, the syngas production capacity of the gasification unit will be increased by 5.4% of the demonstrated production capacity of the existing plant, corresponding to an increase of 7.5 t/h of asphalt feedstock. Therefore a new gasifier was deemed necessary.

Foster Wheeler Italiana and ISAB Energy evaluated various expansion concepts and options for the gasifier capacity and size.

The existing gasifiers run at high average capacity, close to the design conditions. Therefore, in evaluating the project scope, the addition of a gasifier of the same size as the existing units was considered to provide operating flexibility and redundancy. However, the capacity of each of the existing gasifiers is equivalent to some 70 t/h of asphalt feedstock and it was concluded that installing such additional gasifier capacity requires extensive modifications to the existing facilities and the overall total installed cost is not economically justified.

Another option was the installation of a new gasifier capable of processing 18 t/h of asphalt, corresponding to the minimum-sized commercial gasifier available from GE. This provides 10.5 t/h of additional feed processing capacity that can be used to “unload” the existing gasifiers operation at an economic cost. The 10.5 t/h of gasification capacity in excess of that required for the hydrogen demand, in fact, provides an adequate level of flexibility and contingency for the existing IGCC operation improving its availability, and allows an acceptable reduction in average throughput of the existing gasifiers, thereby reducing the operating severity and maintenance requirements.

ISAB Energy has therefore concluded that the addition of a third gasifier of 18t/h of asphalt processing capacity is the most technically and economically viable solution consistent with fulfilling its electrical power export and hydrogen supply objectives.

## The revamping of the existing facilities

The new gasifier and associated hydrogen recovery facilities will be located within the existing facilities and they will be an integral and common part of the operations.

The new scheme of the IGCC is included in the following simplified block flow diagram (Fig. 7), showing the new third gasification train and the new hydrogen production plant. The scheme shows also the new control valve on the existing syngas line to the expander, necessary to regulate the flow rate of syngas through the hydrogen plant.

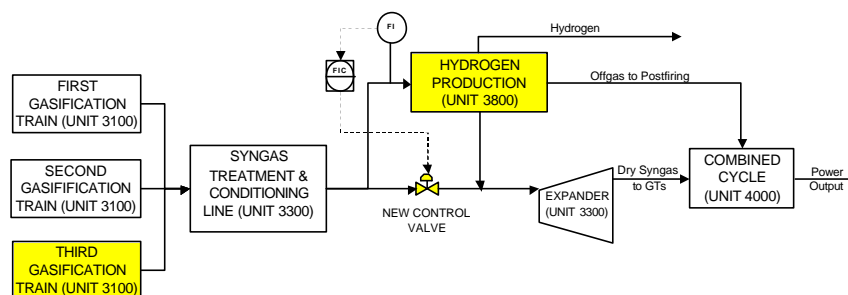


Figure 7 - IGCC Block Flow Diagram

With the addition of the new facilities, the existing units will operate above their present load and, in some cases, above their design capacities. In the undertaken feasibility studies and basic design, FWI evaluated the adequacy of the existing facilities under the new operating conditions. For the existing gasification and carbon recovery units, based on GE gasification technology, the results were confirmed by GE. Other studies have been completed by Ansaldo Energia to assess the operation of the gas turbines with the modified syngas and by Ansaldo Caldaie to verify the adequacy of the HRSG post-firing burners to accept the PSA offgas of the new hydrogen plant.

Based upon these studies carried out during the feasibility and basic design phases, it has been concluded that generally the:

- existing gasification feed systems and syngas treating systems are adequate for the proposed capacity increase, with minor modifications;
- utility and infrastructure systems are able to accommodate the increased asphalt processing and syngas production, specifically the high pressure oxygen availability from the adjacent Air Liquide air separation unit is able to support the increased operating capacity;
- safety relief and flare systems are adequate for the expanded operations;
- control and safety shutdown systems are to maintain the same philosophy and equipment as for the existing facilities in the expansion additions: the control of the new facilities will be integrated in the existing IGCC master controller, while the emergency shutdown system of the new gasifier will be implemented in an expansion of the existing Triconex system managing the existing gasifiers;
- combined cycle is able to process the modified syngas, maintaining the present net power output of 560 MW.

In the following, the new installations and the main required modifications to the existing units are presented.

#### A. Gasification and Carbon Recovery (GE technology)

The new gasifier train includes the following equipment:

- new *gasifier* designed for 18 t/h of charge oil.
- new *gasifier charge oil pump* dedicated to the new gasifier.
- new *syngas scrubber*.
- *start-up quench water pumps* and *sump* to carry on the quench ring cooling during the gasifier start-up and shutdown.
- *new grey water/soot water exchanger*
- *auxiliary items* dedicated to the third gasification line.

The introduction of the new gasifier increases the load of all the existing facilities of this unit that are in common among the gasifiers. Foster Wheeler Italiana verified the operation of these facilities under the new conditions. Only minor modifications were deemed necessary:

- Revamping of the burner cooling water system pumps, to assure the proper cooling of the gasifiers burners.
- New high pressure naphtha pump

- New emergency demineralized water diesel pump to cool the internals of the new gasifier in case of electric power failure.

#### B) New Hydrogen Unit

The new hydrogen production unit mainly consists of a *membrane section* for the hydrogen enrichment of the syngas and a *PSA section* for the production of 20,000 Nm<sup>3</sup>/h of pure hydrogen (>99.5% H<sub>2</sub> content). The residual syngas after hydrogen purification in the PSA section is a PSA offgas at a low pressure of approximately 1.2 barg. This offgas is burnt in new, dedicated low-pressure burners installed in the heat recovery steam generators (HRSGs) of the combined cycle plant.

Only a portion of the syngas produced in the gasifiers is sent to the membranes. The flowrate of this stream is controlled by acting on a new control valve installed on the existing syngas line; this control valve will operate as a hydrogen unit by-pass.

When installing a membrane unit on a syngas circuit, attention must be paid to the possibility of membrane damage by the solvent that could be entrained in the syngas coming from the acid gas removal (AGR). For this reason, upstream of the new hydrogen production facilities, a syngas scrubber is installed, with continuous recirculation of water for the abatement of MDEA solvent possibly dragged from the AGR.

#### C. Gas Turbines

The syngas fed to the gas turbines will have lower hydrogen to carbon monoxide ratio than currently. Ansaldo Energia confirmed that such a ratio will be within the acceptable range of variation. The performance will not therefore be materially impacted, although there will be a minor impact on the gaseous emissions, which will remain largely below the limits allowed to the plant.

#### D. Syngas Cooling, Saturation and Expansion

After studies undertaken by FWI it has been established that the existing facilities for syngas cooling (with heat recovery for steam production and condensate preheating), COS hydrolysis, syngas saturation and expansion are adequate for the proposed capacity increase. The cooling system of this unit has been checked by comparing the thermal design with the operating values. The exchangers appear to have sufficient margin for the new configuration and from overall point of view there are no problem in the unit to achieve the syngas cooling.

The only system that needs a revamp is the *condensate return pumps* that transfer the condensate generated in the syngas cooling from the accumulator to the scrubbers of the gasification unit. With the addition of the third gasifier and a higher syngas flow rate, the operating pump will operate both with higher flowrate and higher head. The new operating conditions are critical. For this reason a new condensate pump, smaller than the existing two, is installed dedicated to the third scrubber. In case of malfunctioning of the third smaller pump it is possible to use one of the two existing pumps as spare.

### E. Sulfur removal

The AGR unit, using MDEA as solvent, shows some operating difficulties when the asphalt fed to the IGCC contains much sulfur and simultaneously the operating conditions of the gasifiers lead to high CO<sub>2</sub> content of the syngas. In these conditions the H<sub>2</sub>S content of the syngas is borderline with the design specification and the CO<sub>2</sub> slip is increased. Without any modification, the situation is expected to become worse after the start of the third gasifier, when the syngas flow rate will be more than now.

To improve the operation of the unit Dow, supplier of the solvent presently used, suggested a new solvent formulation with higher selectivity that should allow the H<sub>2</sub>S specification to be met without increasing the CO<sub>2</sub> slip.

In parallel the amine circulation circuit will be debottlenecked by adding a new control valve on the rich amine circuit.

The sulfur recovery unit (SRU) comprises two 50% operating lines and one stand-by line, with a capacity of 95 tonnes per hour of sulfur per train.

In the future operating conditions, at the same sulfur content in the asphalt (6%wt), the sulfur flow rate is expected to increase by 6%, in proportion to the syngas flow rate. That means that the IGCC will normally operate with two SRU lines and that the third line could be put in operation when the sulfur in the asphalt will be close to the design (6%), to maintain the maximum gasifier load.

### **Production and environmental performances**

The performance of the existing IGCC and of the IGCC revamped to produce hydrogen, are indicated in the following table:

<b>EXPECTED PERFORMANCES OF THE IGCC PLANT</b>			
		<b>Existing IGCC</b>	<b>Revamped IGCC</b>
Feedstock	t/h	139.0	146.5
Oxygen consumption	Nm <sup>3</sup> /h	102,000	107,800
Gross power output	MW	570	570
Combined cycle consumption	MW	10	10
Net power output	MW	560	560
Process and utility consumption	MW	30	30.5
Net IGCC power	MW	530	529.5
Hydrogen production	Nm <sup>3</sup> /h	0	20,000

The table shows that it is possible to produce 20,000 Nm<sup>3</sup>/h of hydrogen and maintain the present electric power output of the combined cycle, by processing 7.5 t/h of additional asphalt. The oxygen consumption is in proportion to the asphalt.

From emission point of view the following consideration can be made:

- The new solvent proposed in the AGRU allows the maintenance of constant SO<sub>2</sub> emissions: in fact the higher efficiency of the new solvent compensates for the increase in flowrate of syngas through the AGRU, and consequently the overall content of H<sub>2</sub>S in the syngas fed to the gas turbines does not increase.
- The gas turbines and post-firing systems of the HRSGs will maintain the same loads as the actual conditions: the NO<sub>x</sub>, CO and particulate emissions are not expected to increase in the future operating conditions.

## Plot Plan

The position of the new facilities is shown in Fig. 8.

In choosing the areas for the installation of the new facilities and the equipment disposition in these areas, ISAB Energy and FWI considered the operational aspects, the accessibility of the site and the adequacy of the plant area for the construction phase.

ISAB Energy wished to locate the third gasifier adjacent to the existing two gasification trains, since this minimises piping runs etc. and maintains the operating area arrangement. An area between the existing units and the soot water storage tank was originally identified as a possible location. Further evaluations on constructability, on-going existing operations and future operations and maintenance led to the conclusion that the existing gasification area is not adequate as it is already congested.

Then, an area adjacent to substation LC2 and between the substation and the knock-out drums of the flare system has been identified as the most appropriate area, as far as operability, constructability and maintainability are concerned. This area is outside of, but relatively close to, the existing gasification island.

The location of the new gasifier outside the existing gasification plot requires some additional equipment and pipes. This is however considered acceptable and ultimately the project and existing facilities benefit from the improved constructability, operation and maintenance as compared to other layouts.

The only equipment that will be located in the present gasification area is the new change oil pump to feed the new gasifier.

In fact it is preferable to maintain all charge oil pumps in the same location, so that common charge oil circuits and auxiliary systems for the pumps can be installed.

It is also proposed that the hydrogen and PSA units be located within the syngas cooling, saturation and expansion area of the plot plan, in an area relatively free of equipment. This choice is a good compromise between two conflicting requirements: 1) to install the new hydrogen production facilities close to the tie-ins on the existing syngas lines and to the pipe way for a safe hydrogen line routing to the Refinery and 2) to minimize the risk related to construction, operation and maintenance within an area already occupied by other facilities.

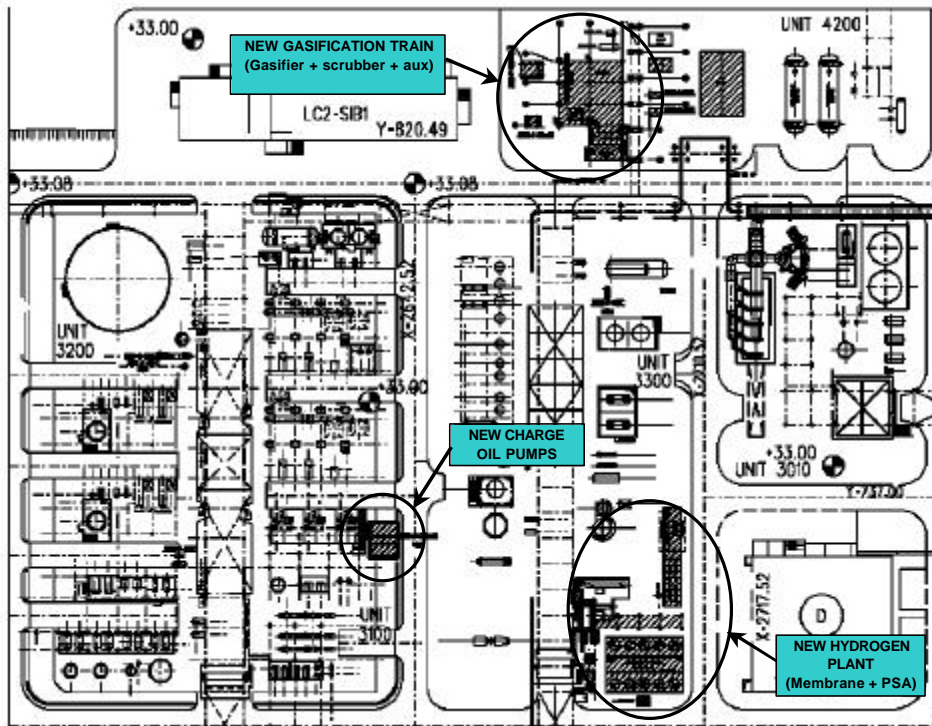


Figure 8 - Plot Plan

### Project execution plan

Subject to detailed development in discussion with the potential EPC contractor, the Feasibility Study proposed a “fast track” strategy with overlap of the permitting, basic design and detailed engineering phases to optimise the overall project schedule

Due to the constraint of early hydrogen unit start-up needed to support the production of the Euro-grade automotive fuels, during the permitting phase ISAB Energy and FWI developed the engineering and procurement activities relevant to long lead items of hydrogen unit. At the end of year 2006, the EPaCm services were awarded to FWI with the target of developing in the first six months the basic and most critical detailed engineering activities, the procurement of long lead items relevant to the gasification unit and the issue of +/-10% total investment cost estimate. Since a general IGCC complex turnaround was already planned in May 2007, during the first six months of the project ISAB Energy and FWI also designed and implemented all the mechanical, instrument and electrical modifications to avoid any further plant shutdown when the hydrogen and gasification units are started up. Actually the project is now in the detailed engineering phase and the construction phase is planned to start in early 2008; the hydrogen unit is planned to be mechanically complete at the end of 2008, while the gasification unit is planned to be ready for commissioning activities on last quarter of year 2009.

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