SP2 Public Summary Report

Based on the Del. 2.5.1: Preliminary documentation of complete plant concepts for all cases

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The aim of the ENCAP's SP2 was the investigation of candidate pre-combustion decarbonisation processes with reference to the IGCC (Integrated Gasification Combined Cycle) for hard coal and lignite and IRCC (Integrated Reforming Combined Cycle) for natural gas. In WP2.5 the overall outline specifications of power plants with and without CO_2 capture were developed, including the preparation of a conceptual design of complete plants. On the basis of the process engineering work during the first period, a complete documentation of all developed plant concepts, with and without CO_2 capture including a techno-economic assessment, has been acquired. The determination and comparison of all technical and economic key figures are examined in order to investigate the commercial introduction of such concept in Europe. Each participating party contributed a detailed description of their section in each concept. RWE, Lurgi and IFP (NG case) were responsible for description of the syngas generation and gas treating units. Siemens handled the Combined Cycle and Air Liquide covered the air separation unit (ASU).Statoil and Siemens contributed know-how for the natural gas concept while RWE and Statoil added their operational experiences. This work will be the basis for the final documentation at the end of the ENCAP project.
The cases examined and compared with the reference cases defined by SP1 are the following:

- *Hard coal IGCC without CO_2-capture (case 2)*
- *Lignite IGCC without CO_2-capture (case 3)*
- *Natural gas ATR with CO_2-capture (case 4)*
- *Hard coal IGCC with CO_2-capture (case5)*
- *Lignite IGCC with CO_2-capture (case 6)*

(Case 1 is correspondent to the reference case for Natural Gas power station and described under responsibility of SP1)

Cases Examined (Configuration Concepts)

Target value for the electric output of the IGCC plant in ENCAP is 800 MWel. Because of the maximum output of the Siemens SGT5-400F (former V94.3A) gas turbine, basically a two train philosophy has been followed for the overall configuration of the plant for all cases. Generally, a two train concept yields higher flexibility and availability than a single train concept. Therefore, this route has been followed for all components of the plants beginning with the ASU, Gasifier, Gas Conditioning and ending with the gas turbine. The biggest ASU available on the market has a capacity of 5000 t O_2/day. Although this exceeds the actual O_2 demand of the plant, the expected advantages in operation of the plant using a separate ASU for each train where the reason for the decision to install two ASU units. This is accompanied by a slight increase in capital costs for the air separation unit.

Case 2 : Hard coal IGCC without CO_2-capture

For case 2 (hard coal IGCC without CO_2-capture), the hard coal is milled and dried from 8% to 3% moisture. For reason of part load operation in case of milling driers failure, two milling driers per train have to be installed resulting in 4 driers to be installed in total. Each drier will be heated with hot inert gas. There is one Gasifier in each train followed by one fly ash removal unit. Both, bottom product and separated fly ash are given to an external dump. There is a separate Gas Conditioning Unit for each train including COS Hydrolysis and MDEA H_2S-Absorption. MDEA Regeneration, Oxy Claus Unit and Tail Gas Hydrogenation are common to both Gas Conditioning Units. The clean hydrogen-rich syngas from both units is combusted in two separate gas turbines followed by a Heat Recovery Steam Generator each. The heat from the flue gas from both trains is recovered by a single steam cycle.

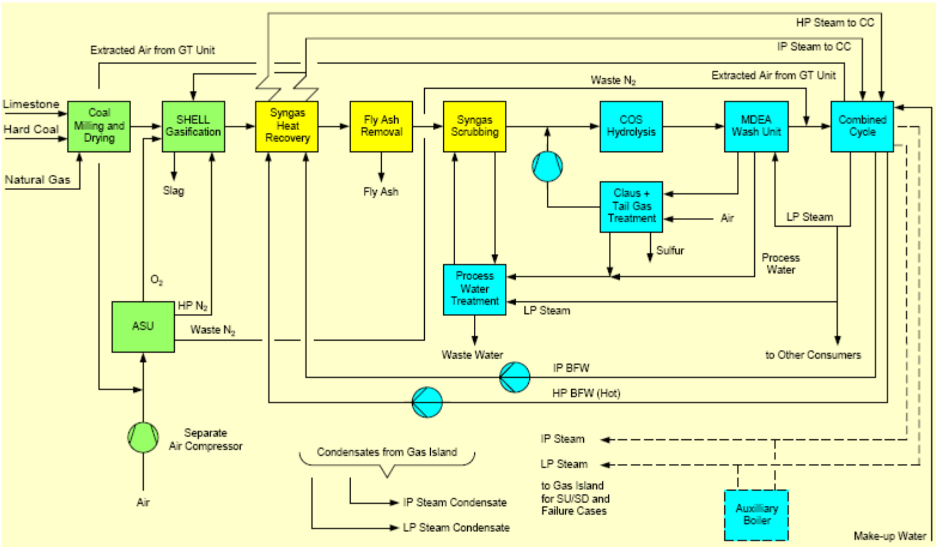

Figure 1: Schematic block diagram of case 2

<u>Case 3: Lignite IGCC without CO_2-capture</u>

For case 3 (lignite IGCC without CO_2-capture), the lignite is milled and dried from 55% to 12% moisture. The WTA lignite drier has a capacity of 125 t/h dry lignite. Therefore, two driers per train have to be installed resulting in 4 driers to be installed in total. One drier in each train will be heated with recirculated heat pump water vapour deriving from the lignite; the other drier will be heated by steam from the combined cycle. There is one Gasifier in each train followed by one fly ash removal unit. Both, bottom product and separated fly ash are combusted in a single CFB unit. There is a separate Gas Conditioning Unit for each train including, COS Hydrolysis and Flexsorb SE + H_2S-Absorption. Flexsorb SE + Regeneration, Clinsulf Unit and Tail Gas Hydrogenation are common to both Gas Conditioning Units. The clean hydrogen-rich syngas from both units is combusted in two separate gas turbines followed by a Heat Recovery Steam Generator each. The heat from the flue gas from both trains is recovered by a single steam cycle.

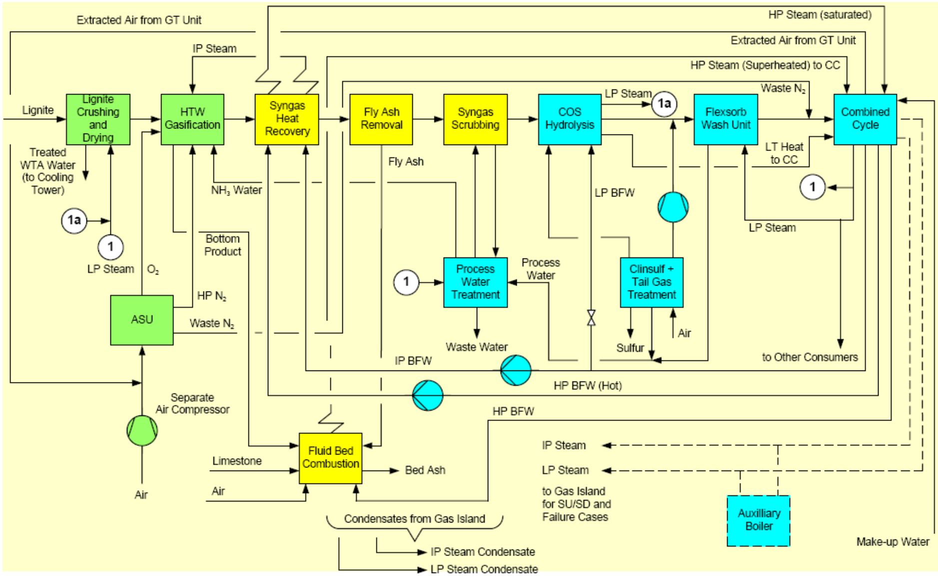

Figure 2: Schematic block diagram of case 3

Case 4: Natural gas ATR with CO_2-capture

In case 4 (natural gas ATR with CO_2-capture), to meet the capacity requirements, the gas production unit is generally designed as two parallel trains (2*50%) consisting of the process units Feed Preheating, Autothermal Reformer, Syngas Cooling. The Process Water Treatment Unit is common to both trains. There is a separate Gas Conditioning Unit for each train including CO Shift, Gas Cooling aMDEA CO_2-Absorption, CO_2 Drying and Compression. The clean hydrogen-rich Syngas from both units is combusted in two separate gas turbines followed by a Heat Recovery Steam Generator each. The heat from the flue gas from both trains is recovered by a single steam cycle. Also, the Water Treatment is common to both trains.

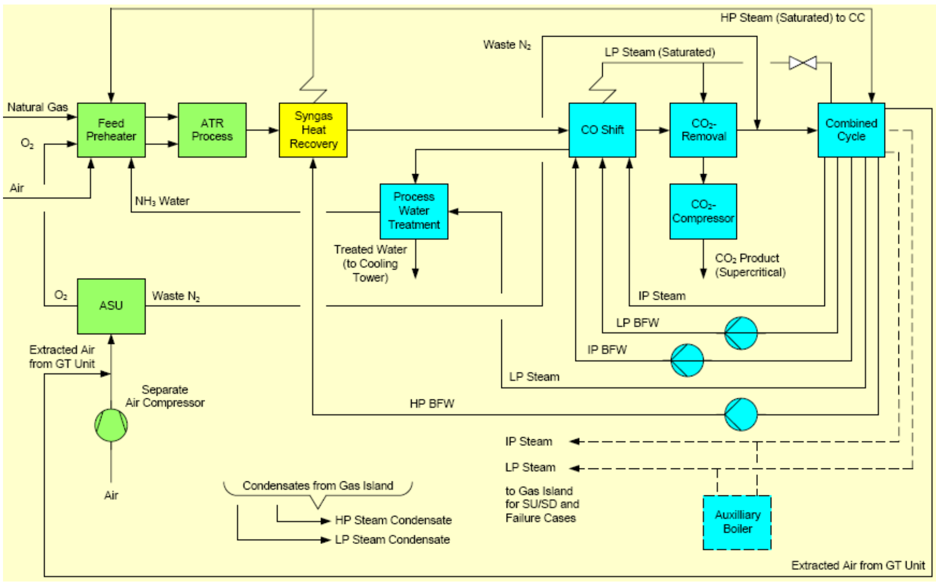

Figure 3: Schematic block diagram of case 4

Case 5: Hard coal IGCC with CO_2-capture

In case 5 (hard coal IGCC with CO_2-capture), the hard coal is milled and dried from 8% to 3% moisture. For reason of part load operation in case of milling driers failure, two milling driers per train have to be installed resulting in 4 driers to be installed in total. Each drier will be heated with hot inert gas. There is one Gasifier in each train followed by one fly ash removal unit. Both, bottom product and separated fly ash are given to an external dump. There is a separate Gas Conditioning Unit for each train including Gas Cooling, Rectisol Prewash, Rectisol H_2S-Absorption, CO Shift and Rectisol CO_2-Absorption. Rectisol Regeneration and CO_2 Compression are common to both Gas Conditioning Units. In addition, there are 2 independent trains of the Oxy Claus Unit and the Tail Gas Hydrogenation. The clean hydrogen-rich Syngas from both units is combusted in two separate gas turbines followed by a Heat Recovery Steam Generator each. The heat from the flue gas from both trains is recovered by a single steam cycle.

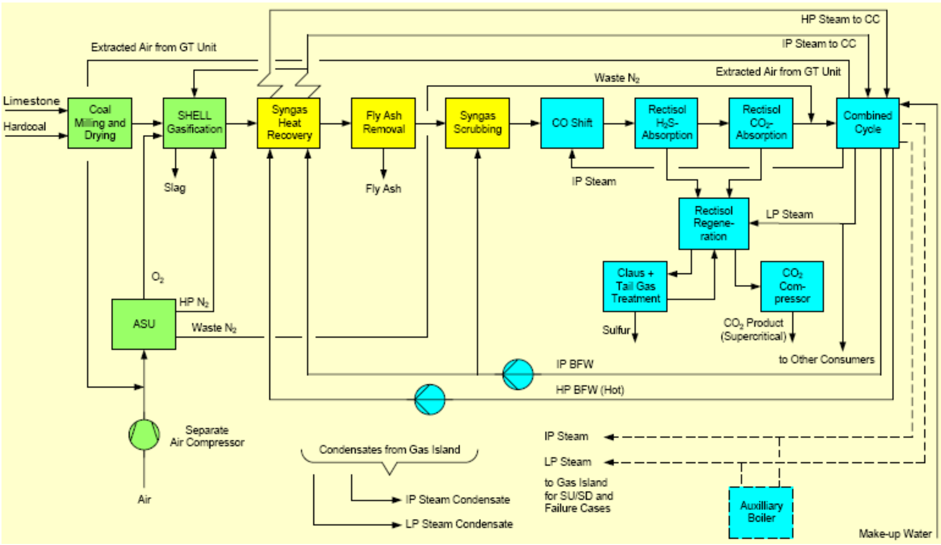

Figure 4: Schematic block diagram of case 5

Case 6:Lignite IGCC with CO_2-capture

In case 6 (lignite IGCC with CO_2-capture), the lignite is milled and dried from 55% to 12 % moisture. The WTA lignite drier has a capacity of 125 t/h dry lignite. Therefore, two driers per train have to be installed resulting in 4 driers to be installed in total. One drier in each train will be heated with recirculated heat pumped water vapour deriving from the lignite, the other drier will be heated by steam from the combined cycle. There is one Gasifier in each train followed by one fly ash removal unit. Both, bottom product and separated fly ash are combusted in a single CFB unit. There is a separate Gas Conditioning Unit for each train including Gas Cooling, Rectisol Prewash, Rectisol H_2S-Absorption, CO Shift and Rectisol CO_2-Absorption. Rectisol Regeneration and CO_2 Compression are common to both Gas Conditioning Units. In addition, there are 2 independent trains of the Oxy Claus Unit and the Tail Gas Hydrogenation. The clean hydrogen-rich Syngas from both units is combusted in two separate gas turbines followed by a Heat Recovery Steam Generator each. The heat from the flue gas from both trains is recovered by a single steam cycle.

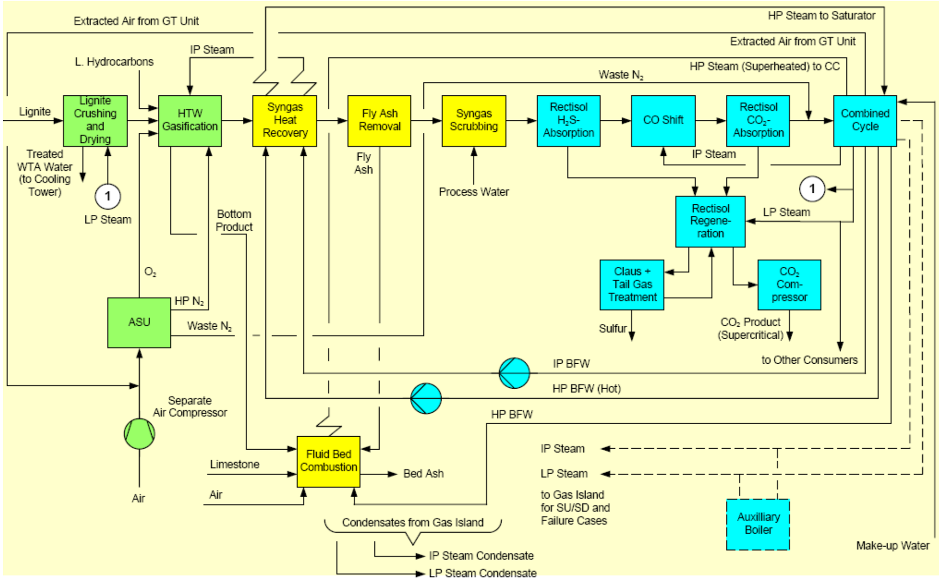

Figure 5: Schematic block diagram of case 6

Summary Performance figures for all cases

		Case 2 Hard coal	Case 3 Lignite	Case 4 Natural gas plus capture	Case 5 Hard coal plus capture	Case 6 Lignite plus capture
Feedstock Mass Flow Feedstock LHV	kg/s MJ/kg	74,08 25,17	179,8 8,89	39,56 46,5	81,5 25,17	198,98 8,89
Thermal Input Feedstock (LHV)	MJ/s	1864,6 + 20,9 (NG)	1598,4	1838,9	2051,4	1768,81
Thermal Syngas Flow to GT	(MJ/s)	1508,94	1463,8	1468	1481	1477
Gross Power Output	MW	986,03	931,74	872,45	956,14	899,4
Gross Efficiency	%	52,82	58,53	47,44	46,61	50,85
Air mass flow to GT	kg/s	269,39	168,23	188,77	294,06	191,05
Aux. Consumption						
~ gasification/reforming	MW	11,54	34,8	0,7	12,7	38,8
~ gas conditioning	MW	3,3	3,27	33,05	88,4	75,4
~ CC	MW	19,7	18,6	17,65	18,6	17,7
~ demand external CW	MW	2,6	1,1	8,6	3,5	2
~ ASU	MW	74,8	47,56	57,8	96,4	48,3
Total Aux. Consumption	**MW**	**111,94**	**105,33**	**117,8**	**219,6**	**182,2**
Net Power Output	**MW**	**874,14**	**826,41**	**754,65**	**736,54**	**717,1**
Net Efficiency	**%**	**46,36**	**51,7**	**41,04**	**35,9**	**40,54**
CO_2 captured	**kg/s**	**-**	**-**	**96**	**184**	**169**
CO_2 capture rate	**%**	**-**	**-**	**92,4**	**92,2**	**85**
CO_2 emissions	**g/kWh**	**746**	**799**	**38**	**79**	**146**

Due to the same technical basis for all cases, that means usage of the same gas turbine (model SGT5-4000F/V94.3 from Siemens), the thermal syngas input is quite equal.

The differences occur due to the different contents of the major components, the amount of air, and the resulting amounts of diluent gases for NOx controlling.

The net efficiencies of the different cases or feed stocks, respectively, can not be compared directly due to the different feed stock characteristics like water content, C-content, etc. But some of the differences in auxiliary consumption can/will be explained. First, coal gasification needs more energy than reforming of natural gas. Hard coal gasification island needs less energy than lignite gasification island, while its Oxygen consumption (directly correlated to energy consumption ofin of ASU) is higher than for lignite gasification.
Compared to cases 2 and 3, the gas cleaning units of cases 4 to 6 need more energy due to the CO_2 capture. And in cases 5 and 6, further electrical energy for cooling is needed for the low temperature physical absorption process Rectisol acid gas removal (H_2S, CO_2 and impurities), more electrical energy for cooling is needed than for case 4 (aMDEA for exclusively CO_2).

The lower capture rate in case 6 is forced by the High-Temperature-Winkler (HTW) gasification process which leads to a certain amount of CH_4 (Methane) in the coal gas which can not be shifted to CO_2 before the CO_2 separation step.