



ReCAP Project

Evaluating the Cost of Retrofitting CO₂ Capture in an Integrated Oil Refinery

Description of Reference Plants

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Background of the Project

In the past years, IEA Greenhouse Gas R&D Programme (IEAGHG) has undertaken a series of projects evaluating the performance and cost of deploying CO₂ capture technologies in energy intensive industries such as the cement, iron and steel, hydrogen, pulp and paper, and others.

In line with these activities, IEAGHG has initiated this project in collaboration with CONCAWE, GASSNOVA and SINTEF Energy Research, to evaluate the performance and cost of retrofitting CO₂ capture in an integrated oil refinery.

The project consortium has selected Amec Foster Wheeler as the engineering contractor to work with SINTEF in performing the basic engineering and cost estimation for the reference cases.

The main purpose of this study is to evaluate the cost of retrofitting CO₂ capture in simple to high complexity refineries covering typical European refinery capacities from 100,000 to 350,000 bbl/d. Specifically, the study will aim to:

- Formulate a reference document providing the different design basis and key assumptions to be used in the study.
- Define 4 different oil refineries as Base Cases. This covers the following:
 - Simple refinery with a nominal capacity of 100,000 bbl/d.
 - Medium to highly complex refineries with nominal capacity of 220,000 bbl/d.
 - ▶ Highly complex refinery with a nominal capacity of 350,000 bbl/d.
- ▶ Define a list of emission sources for each reference case and agreed on CO₂ capture priorities.
- Investigate the techno-economics performance of the integrated oil refinery (covering simple to complex refineries, with 100,000 to 350,000 bbl/d capacity) capturing CO₂ emissions:
 - from various sources using post-combustion CO₂ capture technology based on standard MEA solvent.
 - ▶ from hydrogen production facilities using pre-combustion CO₂ capture technology.
 - using oxyfuel combustion technology applied the Fluid Catalytic Cracker.
- Develop a case study evaluating the constructability of retrofitting CO₂ capture in a complex oil refinery providing key information on the following (but not limited to): plant layout, space requirement, safety, pipeline network modification, access route for equipment, modular construction vs. stick-built fabrication, and others.

This project will deliver "REFERENCE Documents" providing detailed information about the mass and energy balances, carbon balance, techno-economic assumptions, data evaluation and CO₂ avoidance cost, that could be adapted and used for future economic assessment of CCS deployment in the oil refining industry.



Executive Summary

Scope of the present report is to provide a description of the four different oil refineries identified as Base Cases:

- Base Case 1) Simple refinery with a nominal capacity of 100,000 bbl/d.
- Base Case 2 and 3) Medium to highly complex refineries with nominal capacity of 220,000 bbl/d.
- Base Case 4) Highly complex refinery with a nominal capacity of 350,000 bbl/d.

The performance, in terms of mass and energy balances, and CO_2 emissions of the REFERENCE Plants (Base Cases) is the basis for comparison of the effectiveness and cost of the Oil Refinery with CO_2 capture.

In particular, the following figures show the performance, in terms of specific energy consumptions and CO₂ emissions, of the four Base Case Refineries:

Figure 0-1 shows the product slates' of the four Base Cases, reflecting the increasing complexity of the processing scheme from Base Case 1 to 4.

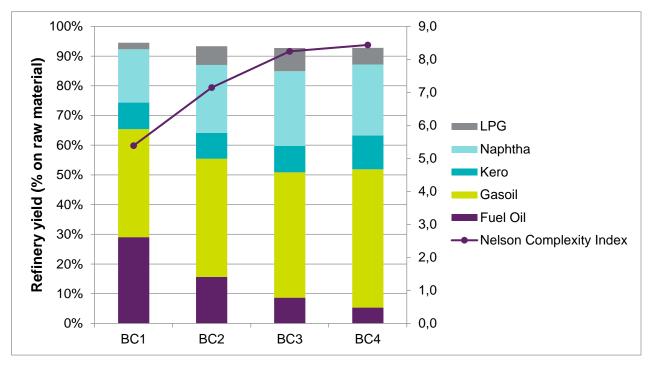


Figure 0-1: Refinery yields in different base case configurations

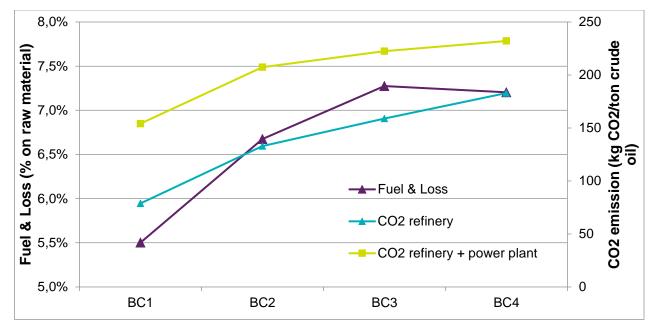
It is worth to highlight that from Base Case 1 to 4 the yield in black products (fuel oil, bitumen, coke and sulphur) decreases while the naphtha and gasoil fractions increase; this is fully in line with refinery configurations, since the more is the complexity (in particular the presence of Fluid Catalytic Cracking, Delayed Coking and Vacuum Gasoil Hydrocraking), the more is the conversion of heavy cuts to lighter and more valuable products.

The market conditions in the past periods have pushed the refineries to upgrade their configuration to process heavier crudes, cheaper than the lighter ones, and to re-process heavy distillate products to obtain more valuable fractions. These energy intensive units, however, demand a greater amount of fuel and, in turn, increase the amount of CO₂ emitted.



Figure 0-2 includes a comparison of specific fuel consumptions and CO_2 emission of the four cases, while Figure 0-3 reports the different fuel mix compositions.

It can be noted that the fuel demand in Base Case 4 is indeed more than 50% bigger than the consumption in Base Case 1, and this trend can be identified in CO_2 emission too.





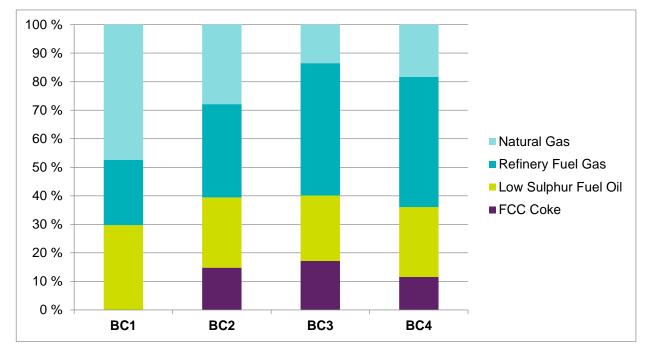


Figure 0-3: Fuel mix composition in different base case configurations

As a conclusion, the four identified base cases can be regarded as a good starting point for evaluating the effects of retrofitting CO₂ capture facilities in existing refineries, different per size and complexity.

The following charts summarize the main CO2 emission sources of the four base case refineries.



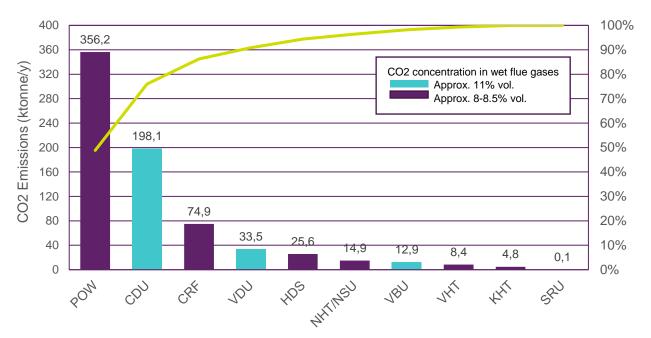


Figure 0-4) Main CO2 emission sources in Base Case 1 refinery

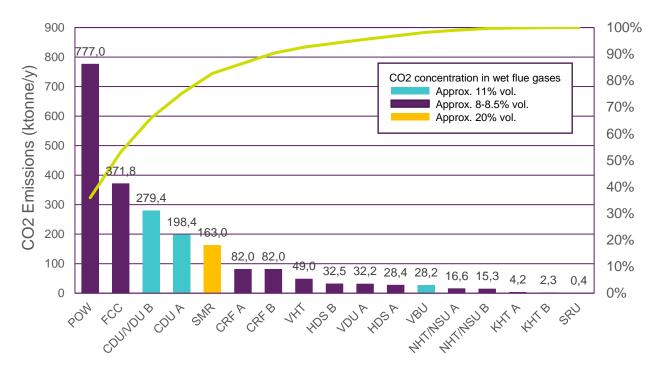
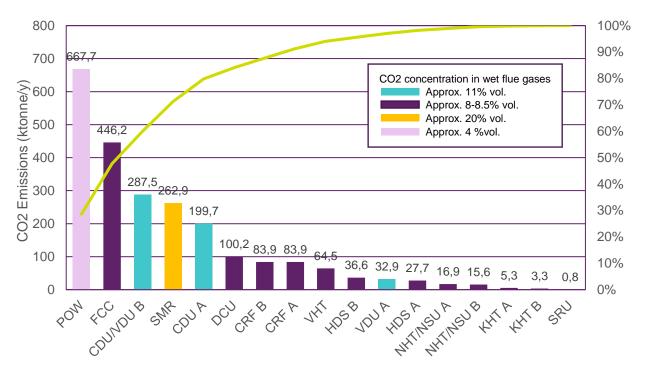
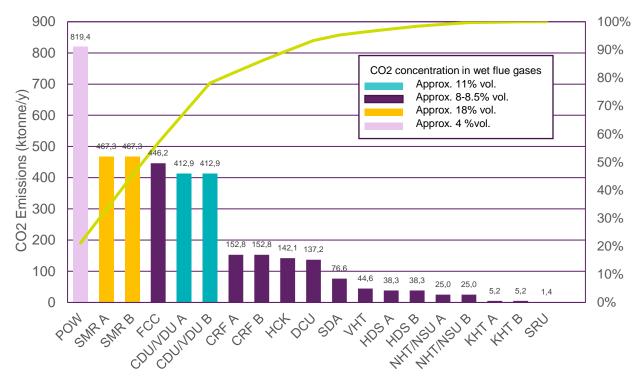


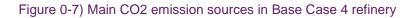
Figure 0-5) Main CO2 emission sources in Base Case 2 refinery













1. Introduction

The performance, in terms of mass and energy balances, and CO₂ emissions of the REFERENCE Plants (Base Cases) are the basis for comparison of the effectiveness and cost of the Oil Refinery with CO₂ capture.

Scope of the present report is to provide a description of the four different oil refineries identified as Base Cases, including the following main information:

- Refinery Block Flow Diagram showing the major processes of the refinery, including the overall mass balance,
- Overall plant layout,
- Refinery fuel balance,
- Hydrogen balance,
- > Breakdown of the utilities consumptions (water, electricity and steam) for each major process,
- Summary of CO₂ emissions/concentrations from individual processes.

It must be emphasised that the base case refinery configurations, capacities and economics are values arrived at by consensus among project partners to provide an "average representation" for the wide array of existing European refineries. These do not represent any specific refinery (or refineries) in operation.

1.1 List of Base Cases

Four Base Cases have been considered which differ in terms of capacity and complexity, so providing a representative sample of most of the existing refineries in Europe.

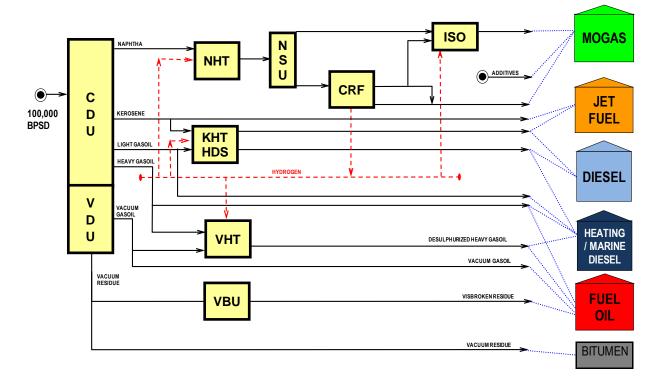
All the assumptions made to build the base cases have been shared among the members of the consortium in order to reflect as much as possible the typical range of configurations, units' capacities, product slates, energy efficiencies, etc. of European refineries.

1.1.1 Base Case 1: Simple Hydro-skimming Refinery

- Capacity: 100,000 bbl/d
- Major Processes:
 - Unit 100: Crude Distillation Unit (CDU)
 - Unit 200: Saturated Gas Plant (SGP)
 - ► Unit 250: LPG Sweetening (LSW)
 - Unit 280: Kerosene Sweetening (KSW)
 - Unit 300: Naphtha Hydrotreater (NHT)
 - ► Unit 350: Naphtha Splitter (NSU)



- Unit 400: Isomerization Unit (ISO)
- ► Unit 500: Catalytic Reformer (CRF)
- ► Unit 550: Reformate Splitter (RSU)
- Unit 600: Kerosene Hydrotreater (KHT)
- Unit 700: Diesel Hydro-desulphurisation Unit (HDS)
- Unit 1100: Vacuum Distillation Unit (VDU)
- Unit 1500: Visbreaker Unit (VBU)
- Unit 2000: Amine Regeneration Unit (ARU)
- Unit 2100: Sour Water Stripper Unit (SWS)
- Unit 2200: Sulphur Recovery Unit (SRU)
- Unit 2300: Waste Water Treatment (WWT)
- Unit 2500: Power Plant (Electricity and Steam Production)
- Unit 3000: Utilities
- Unit 4000: Off-sites Unit



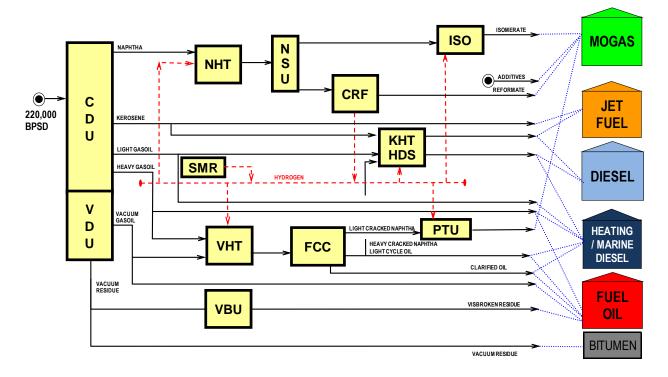




1.1.2 Base Case 2: Medium Conversion Refinery

- Capacity: 220,000 bbl/d
- Major Processes:
 - ► Unit 100: Crude Distillation Unit (CDU)
 - ► Unit 200: Saturated Gas Plant (SGP)
 - ► Unit 250: LPG Sweetening (LSW)
 - ► Unit 280: Kerosene Sweetening (KSW)
 - Unit 300: Naphtha Hydrotreater (NHT)
 - ► Unit 350: Naphtha Splitter (NSU)
 - ► Unit 400: Isomerization Unit (ISO)
 - Unit 500: Catalytic Reformer (CRF)
 - Unit 550: Reformate Splitter (RSU)
 - Unit 600: Kerosene Hydrotreater (KHT)
 - Unit 700: Diesel Hydro-desulphurisation Unit (HDS)
 - Unit 800: Vacuum Gasoil Hydrotreater (VHT)
 - Unit 1000: Fluid Catalytic Cracker (FCC)
 - Unit 1050: FCC Gasoline Post-Treatment Unit (PTU)
 - Unit 1100: Vacuum Distillation Unit (VDU)
 - Unit 1200: Steam Methane Reformer (SMR)
 - Unit 1500: Visbreaker Unit (VBU)
 - Unit 2000: Amine Regeneration Unit (ARU)
 - Unit 2100: Sour Water Stripper Unit (SWS)
 - Unit 2200: Sulphur Recovery Unit (SRU)
 - Unit 2300: Waste Water Treatment (WWT)
 - Unit 2500: Power Plant (POW)
 - ► Unit 3000: Utilities
 - Unit 4000: Off-sites







1.1.3 Base Case 3: High Conversion Refinery

- Capacity: 220,000 bbl/d
- Major Processes:
 - ► Unit 100: Crude Distillation Unit (CDU)
 - ► Unit 200: Saturated Gas Plant (SGP)
 - ► Unit 250: LPG Sweetening (LSW)
 - ► Unit 280: Kerosene Sweetening (KSW)
 - Unit 300: Naphtha Hydrotreater (NHT)
 - Unit 350: Naphtha Splitter (NSU)
 - Unit 400: Isomerization Unit (ISO)
 - ► Unit 500: Catalytic Reformer (CRF)
 - ► Unit 550: Reformate Splitter (RSU)
 - ► Unit 600: Kerosene Hydrotreater (KHT)
 - Unit 700: Diesel Hydro-desulphurisation Unit (HDS)
 - Unit 800: Vacuum Gasoil Hydrotreater (VHT)



- Unit 1000: Fluid Catalytic Cracker (FCC)
- Unit 1050: FCC Gasoline Post-Treatment Unit (PTU)
- Unit 1100: Vacuum Distillation Unit (VDU)
- Unit 1200: Steam Methane Reformer (SMR)
- Unit 1400: Delayed Coker Unit (DCU)
- Unit 2000: Amine Regeneration Unit (ARU)
- Unit 2100: Sour Water Stripper Unit (SWS)
- Unit 2200: Sulphur Recovery Unit (SRU)
- Unit 2300: Waste Water Treatment (WWT)
- ► Unit 2500: Power Plant (POW)
- ► Unit 3000: Utilities
- ► Unit 4000: Off-sites

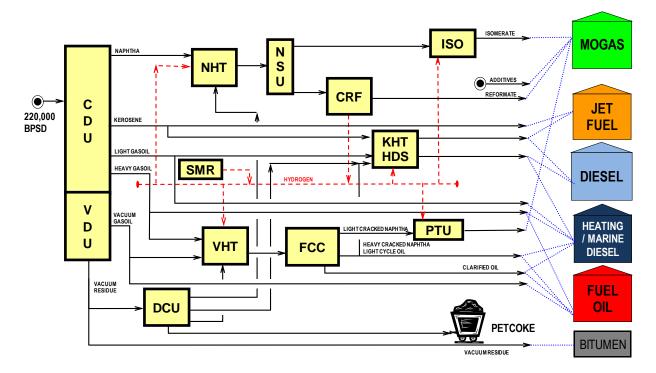


Figure 1-3: Simplified flow diagram for Base Case 3



1.1.4 Base Case 4: High Conversion Refinery

- Capacity: 350,000 bbl/d
- Major Processes:
 - ► Unit 100: Crude Distillation Unit (CDU)
 - ► Unit 200: Saturated Gas Plant (SGP)
 - ► Unit 250: LPG Sweetening (LSW)
 - ► Unit 280: Kerosene Sweetening (KSW)
 - Unit 300: Naphtha Hydrotreater (NHT)
 - ► Unit 350: Naphtha Splitter (NSU)
 - ► Unit 400: Isomerization Unit (ISO)
 - Unit 500: Catalytic Reformer (CRF)
 - Unit 550: Reformate Splitter (RSU)
 - Unit 600: Kerosene Hydrotreater (KHT)
 - Unit 700: Gasoil Hydro-desulphurisation Unit (HDS)
 - Unit 800: Vacuum Gasoil Hydrotreater (VHT)
 - ► Unit 900: Hydrocracker Unit (HCK)
 - ► Unit 1000: Fluid Catalytic Cracker (FCC)
 - Unit 1050: FCC Gasoline Post-Treatment Unit (PTU)
 - Unit 1100: Vacuum Distillation Unit (VDU)
 - Unit 1200: Steam Methane Reformer (SMR)
 - Unit 1300: Solvent Deasphalting Unit (SDA)
 - Unit 1400: Delayed Coker Unit (DCU)
 - Unit 2000: Amine Regeneration Unit (ARU)
 - Unit 2100: Sour Water Stripper Unit (SWS)
 - Unit 2200: Sulphur Recovery Unit (SRU)
 - Unit 2300: Waste Water Treatment (WWT)
 - Unit 2500: Power Plant (POW)
 - ► Unit 3000: Utilities
 - Unit 4000: Off-sites



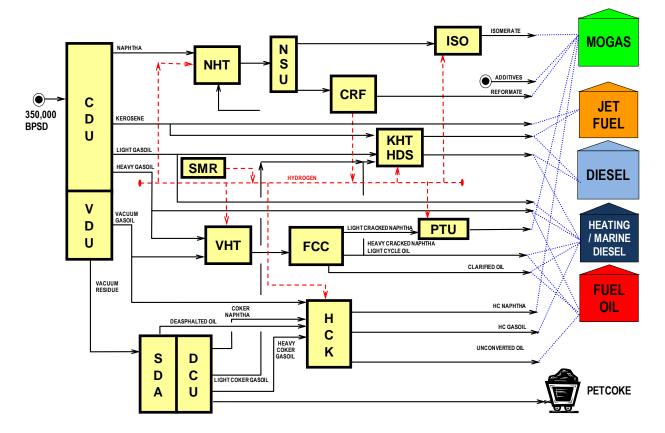


Figure 1-4: Simplified flow diagram for Base Case 4



2. Methodology

2.1 Refinery balances

A linear programming model has been built for each one of the four Base Cases, in order to produce consistent and realistic refinery balances.

Linear programming (LP) is an optimisation technique widely used in petroleum refineries.

LP models of refineries are used for capital investment decisions, the evaluation of term contracts for crude oil, spot crude oil purchases, production planning and scheduling, and supply chain optimisation.

Haverly Systems GRTMPS software (v. 5.0) has been used to build the refinery LP models.

For each process unit, typical yields' structure, products' qualities and specific utility consumptions have been input, based on Amec Foster Wheeler in-house database.

In particular, as far as the primary distillation units are concerned (i.e. Crude Atmospheric and Vacuum Units), some process simulation models have been run in order to evaluate the distillates' yields and main qualities.

The model has been run based on:

- > a consistent set of crude, natural gas and products' prices,
- a typical (average) crude diet,
- typical (average) units' sizes and utilization factors,
- European products' specifications,
- typical products' slates, reflecting the average proportions among gasoline markets (i.e. EU/US Export), middle distillates grades (jet fuel/automotive diesel/marine diesel/heating oil) and fuel oil/bitumen productions.

Moreover, in the LP model, an internal production of power and steam to satisfy the refinery needs has been considered.

In the following sections, more details are provided to describe the main input data and constraints of the linear programming models.

Reference is also made to the Reference Document – Technical Basis, including most of the basic assumptions made to develop the refinery balances.

2.2 Refinery layouts

The refinery layouts for the four Base Cases have been developed based on the processing schemes and units' capacities defined as a result of the modelling optimisation.

The layouts have been conceived starting from real examples (real sites) in Amec Foster Wheeler in-house database, to reflect as a much as possible the typical arrangement of European refineries. The intent of presenting typical layouts for the Base Cases is to create a reasonable background for evaluating, in a second phase of this Study, the impact of retrofitting CO₂ capture facilities in an existing site with the relevant constraints (e.g. the limitations in the available plot area, the need for long interconnecting ducts between the existing and the new plants, etc.)



The following notes apply to the Base Case layouts:

- Process units' block is normally located in a central area of the plot;
- Utility block is located in a lateral position with respect of process units;
- Storage tank areas are all around the units' block. Different tank sizes are shown for crude, finished products, intermediate products;
- Main pipe-racks connecting the various process units and utility blocks are shown;
- Jetties and truck loading facilities for sending/receiving products are shown;
- Flare and Waste Water Treatment facilities, which are very demanding in terms of plot area, are shown;
- > The main gaseous emission points (e.g. fired heaters stacks) are shown.



3. Design Basis

3.1 Crudes

In order to develop the refinery balances, the following crudes have been considered:

- Ekofisk (Norway), 42.4° API, Sulphur content 0.17% wt.
- Bonny Light (Nigeria), 35.0° API, Sulphur content 0.13% wt.
- Arabian Light (Saudi Arabia), 33.9° API, Sulphur content 1.77% wt.
- ▶ Urals Medium (Russia), 32.0° API, Sulphur content 1.46% wt.
- Arabian Heavy (Saudi Arabia), 28.1° API, Sulphur content 2.85% wt.
- Maya (Mexico), 21.7°API, Sulphur content 3.18% wt.

The crude basket has been selected as representative of different supply regions, products' yields and qualities, and it is deemed to reflect with a fair representation the "average" operation of the four European refineries identified as Base Cases.

As far as Maya crude is concerned, it has been considered to be processed only in mixture with Arabian Light, in the proportion 50/50% wt. This to consider the fact that the typical crude distillation units in Europe were not originally designed for extra-heavy crudes and can accommodate them only in blended mode.

The chart in Figure 3-1 shows the distillation curves of the six crudes considered in the Study.

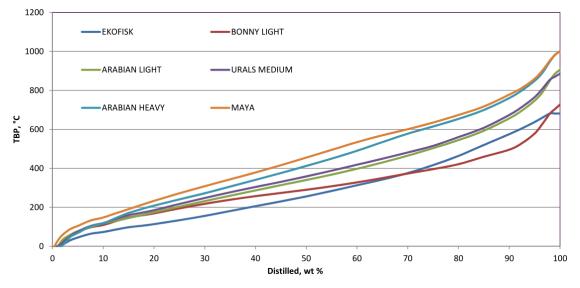


Figure 3-1: Crude Distillation Curves

The crude data grids, reporting the main properties of each crude oil and relevant cut fractions (theoretical, see also paragraph 4.1), are enclosed in the Reference Document – Technical Basis - Annex B.



As far as the proportions among the different crudes are considered, the following have been forced into the LP models to produce the optimised refinery balances:

- Maya Blend: 4% minimum.
- Arabian Heavy: 3% minimum (*)
- Arabian Light: 10% minimum.
- Urals: 30% minimum.
- Bonny Light: 30% maximum (*).
- Ekofisk: no limit. Balancing crude.

(*) Arabian Heavy increased to 10% minimum and Bonny Light decreased to 23% maximum in Base Case 3 and Base Case 4.

3.2 Product Specifications

The refinery product specifications considered in this Study are reported in the Reference Document – Technical Basis - Annex C.

No seasonal variations are considered.

3.3 Market Constraints

Products' market constraints have been input in the LP model in order to "drive" the model solution to reflect the typical products' slates of the European refineries.

3.3.1 Gasoline

Gasoline Export to US is 30 to 40% wt. of the total gasoline production. The rest of gasoline production is sold in Europe.

3.3.2 Jet fuel

Sales of Jet Fuel represent approx. 10% wt. of the total crude intake for Base Case 1 to Base Case 3.

Jet Fuel production is increased to 13% wt. of total crude intake for Base Case 4.

3.3.3 Gasoils

Automotive Diesel is minimum 75% wt. of the total gasoil production.

Marine Diesel is maximum 10% wt. of the total gasoil production.

3.3.4 Bitumen

Bitumen sold in Base Case 1, 2 and 3 is approx. 2.5% wt. of the total crude intake.

Bitumen is not produced in Base Case 4, since in such a deep conversion refinery it is considered to maximise the distillates' production.



3.4 Raw Material and Product Prices

The sets of prices considered in the LP models have been agreed among the members of the Consortium. They have been provided to Amec Foster Wheeler only for the purpose of calculations and they do not represent prices for any specific refinery.

3.5 Utility Conditions

In the LP models, the utility conditions have been considered as per Reference Document – Technical Basis - Paragraph 7.4.

3.6 On-stream Factor

350 operating days per year have been considered to develop the overall material balances of the four Base Case refineries, reflecting as an average:

- > 1 week shutdown per year for unplanned shutdowns/catalyst replacements/minor repairs, plus
- ▶ 4 weeks general planned turnaround every 4 years for maintenance/major repairs.

3.7 Imported Vacuum Gasoil

Vacuum Gasoil is imported in some Base Cases in order to saturate the capacity of the heavy gasoil conversion units (e.g. Fluid Catalytic Cracking). The quality of imported Vacuum Gasoil is assumed equal to the quality of Heavy Vacuum Gasoil (nominal TBP cut range 420÷530°C) obtained by distillation of the Urals crude.

3.8 Refinery Fuel Oil

Low Sulphur Fuel Oil with 0.5% wt. Sulphur content is burnt in some of the refinery heaters.

Reference is made to Reference Document – Technical Basis - Paragraph 5.1 for the main properties of Low Sulphur Fuel Oil.

The heaters in the following process units have been considered 100% fuel oil fired:

- Unit 100: Crude Distillation Unit (CDU)
- Unit 1100: Vacuum Distillation Unit (VDU)
- Unit 1500: Visbreaker Unit (VBU) (*)

(*) VBU is present only in Base Case 1 and Base Case 2.

3.9 Refinery Fuel Gas

With the exception of the fired heaters burning fuel oil listed in the previous paragraph 3.8, the other refinery heaters and the Power Plant are 100% gas fired.

The off-gases produced in the various process units, after removal of H_2S in amine absorbers (to achieve a residual H_2S content of 50 ppm vol. max.), are collected into a Refinery Fuel Gas system to constitute the primary fuel of the refinery. Imported natural gas is mixed with refinery off-gases to saturate the fuel demand.



Reference is made to Reference Document – Technical Basis - Paragraph 4.2 and 5.2, respectively for the quality of natural gas and refinery off-gases (average) used for combustion calculations.

3.10Bio-additives

Bio-ethanol is an additive to European Gasoline, while Bio-diesel is an additive to Automotive Gas Oil (Diesel).

To produce the typical refinery balances, the quantity of bio-additives in each finished product has been set/limited to the values reflecting the average European qualities:

- bio-ethanol blended into European Gasoline has been limited to 5% vol. max (despite the "official" specification is limiting the bio-ethanol content to 10% vol. max.);
- bio-diesel has been fixed in the range 6÷7% vol. on Diesel.



4. General data and assumptions

This chapter includes the sets of data and assumptions, common to all the Base Cases, used to build the refinery LP models.

The methodology normally used for refinery configuration studies has been adopted, trying however to:

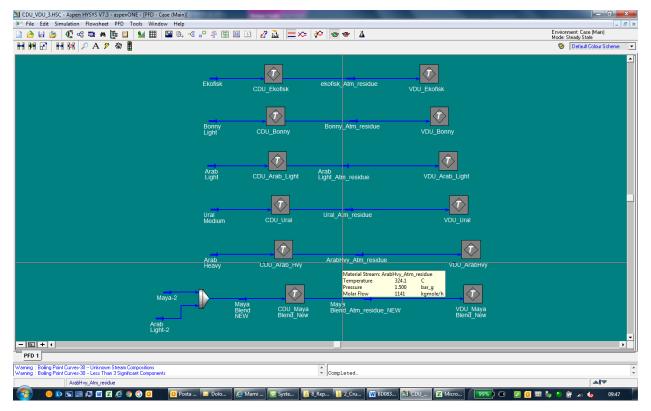
- > remove all the site-specific constraints coming from Amec Foster Wheeler past projects;
- obtain generic but realistic balances, with the level of accuracy needed for the purposes of ReCAP Project.

The valuable input from the members of the Consortium, has been used to optimise the refinery LP model calibration.

For the purpose of this study the capacity of the majority of the units has been adjusted to provide a utilisation rate over 90%. Exceptions to this are the sulphur recovery units and the steam reformers.

4.1 Primary Distillation Units

In order to produce the refinery balances, process simulation models have been created for Crude Distillation Unit (CDU) and Vacuum Distillation Unit (VDU).



Aspentech Hysys v.7.3 is the software used for process simulation.

Figure 4-1: Main flowsheet of CDU/VDU simulation



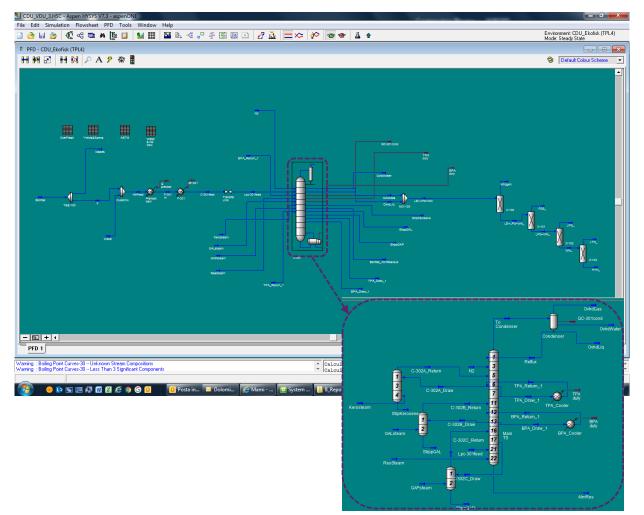


Figure 4-2: Flowsheet of CDU simulation model



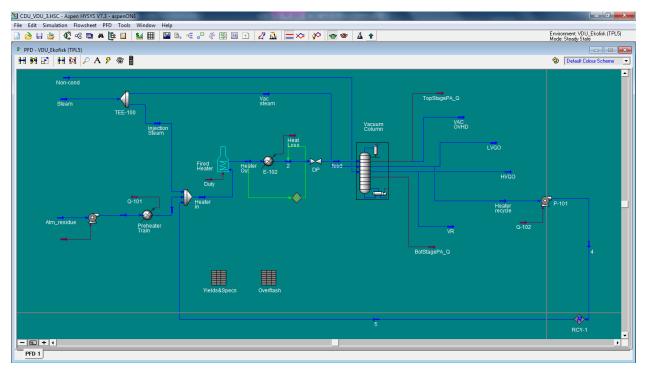


Figure 4-3: Flowsheet of VDU simulation model

The aim of simulation activity is to obtain crude cuts' yields and properties more realistic than the theoretical ones directly retrievable from the crude assay. As a matter of fact, by building a simulation model, the effect of distillation real efficiencies can be properly taken into account, with the consequent impacts on the size and duty of the downstream treating/cracking units.

Table 4-1, Table 4-2, Table 4-3 and Table 4-4 include the sets of yields and main qualities of the straightrun distillation cuts as resulting from the simulation activity.

Crude cuts			Yields on	crude, wt%		
	EKOFISK	BONNY	ARAB LT	URALS	ARAB HY	MAYA BL
Offgas + LPG	1.65%	1.31%	0.89%	1.55%	2.03%	0.79%
Light Naphtha	10.57%	4.44%	3.70%	3.90%	4.04%	3.12%
Heavy Naphtha	19.30%	10.31%	11.17%	8.23%	6.93%	9.04%
Full Range Naphtha	29.87%	14.75%	14.87%	12.13%	10.97%	12.16%
Kero	18.21%	20.29%	15.70%	15.09%	11.95%	13.10%
Light Gasoil (LGO)	18.30%	29.79%	22.09%	21.49%	17.85%	19.50%
Heavy Gasoil (HGO)	4.54%	5.30%	3.50%	3.40%	2.84%	3.20%
Atmospheric Residue	27.43%	28.56%	42.95%	46.34%	54.36%	51.25%
Light Vacuum Gasoil (LVGO)	3.13%	9.43%	7.19%	6.86%	5.55%	6.00%
Heavy Vacuum Gasoil (HVGO)	12.21%	11.63%	13.97%	16.19%	13.31%	14.06%
Vacuum Residue	12.09%	7.50%	21.79%	23.29%	35.50%	31.19%

Table 4-1: Yields of crude distillation cuts



Crude cuts SG EKOFISK BONNY ARAB LT URALS **ARAB HY** MAYA BL Light Naphtha 0.712 0.702 0.675 0.701 0.640 0.674 0.746 Heavy Naphtha 0.768 0.772 0.742 0.733 0.738 Full Range Naphtha 0.727 0.747 0.749 0.728 0.696 0.721 Kero 0.801 0.828 0.802 0.799 0.800 0.798 Light Gasoil (LGO) 0.849 0.871 0.853 0.858 0.866 0.858 Heavy Gasoil (HGO) 0.910 0.898 0.879 0.893 0.903 0.906 Atmospheric Residue 0.953 0.915 0.948 0.960 0.984 0.990 Light Vacuum Gasoil (LVGO) 0.884 0.900 0.901 0.896 0.908 0.908 Heavy Vacuum Gasoil (HVGO) 0.906 0.928 0.930 0.930 0.939 0.939 Vacuum Residue 0.938 1.019 0.977 1.002 1.033 1.015

Table 4-2: Specific gravity (SG) of crude distillation cuts

Table 4-3: Sulphur content of crude distillation cuts

Crude cuts			Sulph	ur, wt%		
	EKOFISK	BONNY	ARAB LT	URALS	ARAB HY	MAYA BL
Light Naphtha	0.00007	0.00232	0.06510	0.00085	0.00706	0.05547
Heavy Naphtha	0.00257	0.00786	0.03610	0.01310	0.01320	0.07052
Full Range Naphtha	0.00168	0.00619	0.04331	0.00916	0.01094	0.06660
Kero	0.018	0.027	0.086	0.183	0.280	0.268
Light Gasoil (LGO)	0.111	0.097	0.981	1.011	1.530	1.362
Heavy Gasoil (HGO)	0.242	0.201	2.175	1.590	2.385	2.366
Atmospheric Residue	0.481	0.298	3.399	2.451	4.440	3.990
Light Vacuum Gasoil (LVGO)	0.258	0.215	2.216	1.627	2.426	2.386
Heavy Vacuum Gasoil (HVGO)	0.379	0.280	2.764	2.010	2.768	2.866
Vacuum Residue	0.642	0.430	4.201	3.000	5.386	4.809

Table 4-4: Main properties (other than Sulphur and SG) of Atmospheric and Vacuum Residue

Crude cuts	Conradson Carbon Residue (CCR), wt%					
	EKOFISK	BONNY	ARAB LT	URALS	ARAB HY	MAYA BL
Atmospheric Residue	4.8	3.3	10.5	7.4	14.5	14.8
Vacuum Residue	11.0	13.6	20.6	15.0	22.8	24.9

Crude cuts	Kinematic viscosity at 50°C, cSt					
	EKOFISK	BONNY	ARAB LT	URALS	ARAB HY	MAYA BL
Atmospheric Residue	213	178	434	560	2270	5215
Vacuum Residue	7147	13644	36679	68038	343155	2158606

Only Vacuum Residue from heavy crudes, i.e. Arabian Heavy and Maya Blend, is considered suitable for Bitumen production.



4.2 Specific Hydrogen Consumptions

Hydrogen balances have been developed by considering the units' specific hydrogen demands reported in Table 4-5.

The following notes apply:

- Specific consumptions are dependent on feed quality;
- Specific consumptions include chemical consumptions, solution losses and mechanical losses.

The hydrogen balances are reported in the block flow diagrams developed for each Base Case (reference is made to Figure 5-1, Figure 6-1, Figure 7-1 and Figure 8-1).

Unit			Feed	H ₂ consumption (wt% on feed)
0300	NHT	Naphtha Hydrotreater	Straight-run Naphtha	0.12
			VB Naphtha/Coker Naphtha	0.15
0400	ISO	Isomerization	Hydrotreated Light Naphtha	0.085
0600A	KHT	Kero HDS	Straight-run Kerosene	0.2
0700A	HDS	Gasoil HDS	Straight-run Light Gasoil	0.7
			VB Gasoil	0.8
			Light Coker Gasoil	0.8
			Light Cycle Oil	0.8
			Heavy Cracked Naphtha	0.25
0800	VHT	Vacuum Gasoil Hydrotreater	Straight-run Heavy Gasoil	1.2
			Light Vacuum Gasoil	1.2
			Heavy Vacuum Gasoil	1.5
			Heavy Coker Gasoil	1.5
			Deasphalted Oll	1.57
0900	HCK	Vacuum Gasoil Hydrocracker	Straight-run Heavy Gasoil	2.0
			Light Vacuum Gasoil	2.0
			Heavy Vacuum Gasoil	2.9
			Heavy Coker Gasoil	4.0

Table 4-5: Specific hydrogen consumptions of process units



4.3 Sulphur Recovery

The H_2S produced in the desulphurization units will be recovered by means of Amine Washing and Regeneration Unit (Unit 2000 – ARU) and Sour Water Stripper (Unit 2100 – SWS). The acid gases recovered from the top of Amine Regenerator and the Sour gases from the top of the SWS column are then sent to Sulphur Recovery Unit (Unit 2200 – SRU). An overall sulphur recovery of 99.5% has been considered, assuming that a Tail Gas Treatment section is installed downstream the SRU Claus section.

4.4 Utility Consumptions

The following main utility balances have been developed:

- Fuel Gas
- Fuel Oil
- Electric Power
- Steam (High Pressure, Medium Pressure, Low Pressure)
- Cooling Water

The specific utility consumptions of the main process units have been retrieved from Amec Foster Wheeler in-house database, which has been populated with data of past Projects. Reference is made to Table 4-7 for the values considered in the LP models.

On top of the demand of the main process units, a refinery base load of power and steam is considered, to take into account all the remaining users (e.g. minor process units, utility and offsite units, buildings, etc.). Refinery base load is different for the various cases, depending on the size/complexity of the refinery. Reference is made to Table 4-6 for the base loads accounted for in the overall utility balances.

CASE	REFINERY BASE LOAD					
	EL. POWER MW	LPS t/h	MPS t/h	HPS t/h		
BASE CASE 1	15	20	20	10		
BASE CASE 2	22.5	30	30	15		
BASE CASE 3	22.5	30	30	15		
BASE CASE 4	30	40	40	20		

Table 4-6: Refinery base loads of power and steam



Table 4-7: Specific utility consumptions for main process units

200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	CDU SGP NHT ISO CRF HDS VGO HDT HCK FCC	1-BD-0839A The Netherlands Crude Distillation Unit Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS Gasoil HDS	Capacity expressed as t feed t feed t feed t feed	EL. POWER Rated kWh/unit 5.8	SEL FIRED FUEL Gcal/unit 0.128		CIFIC CONS LP MODELS IG W. DT °C		MPS t/unit	HPS	
JOB NO: LOCATION: PROCESS UNITS 100 200 300 350 400 500 600 600 600 700 800 VG 900 1000 1100 1200 1100 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	CDU SGP NHT ISO CRF HDS VGO HDT HCK FCC	The Netherlands Crude Distillation Unit Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	expressed as t feed t feed t feed	Rated kWh/unit	FIRED FUEL Gcal/unit	FOR COOLIN Flow	L P MODELS IG W. DT	LPS	MPS	HPS	
LOCATION: PROCESS UNITS 100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 A UXILARY UNITS 2000 2100	CDU SGP NHT ISO CRF HDS VGO HDT HCK FCC	The Netherlands Crude Distillation Unit Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	expressed as t feed t feed t feed	Rated kWh/unit	FUEL Gcal/unit	COOLIN Flow	IG W. DT	LPS		HPS	
PROCESS UNITS 100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1 1300 1400 1500 AUXILIARY UNITS 2000 2100	CDU SGP NHT ISO CRF KHT HDS VGO HDT HCK FCC	Crude Distillation Unit Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	expressed as t feed t feed t feed	Rated kWh/unit	FUEL Gcal/unit	COOLIN Flow	IG W. DT	LPS		HPS	
100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	SGP NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	expressed as t feed t feed t feed	Rated kWh/unit	FUEL Gcal/unit	Flow	DT			HPS	
100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	SGP NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	expressed as t feed t feed t feed	kWh/unit	Gcal/unit			t/unit	t/unit		
100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	SGP NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	t feed t feed t feed	kWh/unit	Gcal/unit			t/unit	t/unit		
100 200 300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	SGP NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	t feed t feed	5.8	0.128				vunit	t/unit	
200 300 350 400 500 600 700 800 VG 900 1000 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	SGP NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Saturated Gas Plant Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	t feed t feed	5.8	0.128						
300 350 400 500 600 700 800 VG 900 1000 1100 1200 1300 1500 AUXILIARY UNITS 2000 2100	NHT NSU ISO CRF KHT HDS VGO HDT HCK FCC	Naphtha HDT Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	t feed			1.2	10	0.065	0.018	0.004	
350 400 500 600 700 800 900 1000 1200 1300 1500 AUXILIARY UNITS 2000	NSU ISO CRF KHT HDS VGO HDT HCK FCC	Naphtha Splitter Isomerization Catalytic Reforming Kero HDS	t feed			incl	uded in CDU				
400 500 600 700 800 VG 900 1000 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	ISO CRF KHT HDS VGO HDT HCK FCC	Isomerization Catalytic Reforming Kero HDS		3.6	0.033	2.2	10	-0.006	0.000	0.110	
500 600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILARY UNITS 2000 2100	CRF KHT HDS VGO HDT HCK FCC	Catalytic Reforming Kero HDS	t food	2.7	0.040	0.2	10	0.000	0.000	0.000	
600 700 800 VG 900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	KHT HDS VGO HDT HCK FCC	Kero HDS	L IEEU	19.8	0.000	2.2	10	0.500	0.069	0.257	
700 800 VG 900 1000 1100 1100 1200 1100 1300 1100 1400 11500 AUXILIARY UNITS 2000 2100 1100	HDS VGO HDT HCK FCC		t feed	33.5	0.561	10.3	10	0.000	0.000	-0.134	
800 VG 900 1000 1100 1200 1300 1400 1500 2000 2000 2100	Vgo HDT HCK FCC	Gasoil HDS	t feed	6.1	0.034	2.8	10	0.000	0.059	0.000	
900 1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	HCK FCC		t feed	13.2	0.093	1.3	10	0.000	0.018	0.000	
1000 1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100	FCC	VGO Hydrotreating	t feed	34.9	0.124	0.03	10	0.021	0.020	0.000	
1100 1200 1300 1400 1500 AUXILIARY UNITS 2000 2100		HP Hydrocracking	t feed	68.6	0.214	0.9	10	-0.096	0.000	0.000	
1200 1300 1400 1500 A UXILIA RY UNITS 2000 2100 550 150 150 150 150 150 150 150 150		Fluid Catalytic Cracking	t feed	5.0	0.376	48.3	10	0.000	0.133	0.085	
1300 1400 1500 AUXILIARY UNITS 2000 2100	VDU	Vacuum Distillation Unit	t feed	4.7	0.059	10.9	10	0.016	0.063	0.000	
1400 1500 AUXILIARY UNITS 2000 2100	SMR	Steam Reforming & PSA	t feed	75.8	2.689	11.6	10	0.000	0.000	-3.032	
1400 1500 AUXILIARY UNITS 2000 2100	SDA	Solvent Deasphalting	t feed	20.5	0.225	0.2	10	0.000	0.081	0.000	
AUXILIARY UNITS 2000 2100		Delayed Coking	t feed	0.0	0.000	0.0	10	0.000	-0.044	0.040	
AUXILIARY UNITS 2000 2100		Visbreaker Unit	t feed	4.7	0.059	10.9	10	0.016	0.063	0.000	
2000 2100							-				
2100		Amine Washing and Regeneration	t feed (H2S)	7.458	0.000	1.1	10	0.532	0.000	0.000	
		Sour Water Stripper					d in BASE LOAD				
2200		Sulphur Recovery Unit	t feed (H2S)	5.364	0.036	3.5	10	0.000	-0.140	0.000	
	TGT	Tail Gas Treatment					uded in SRU				
	-	Waste Water Treatment					d in BASE LOAD				
POWER UNITS											
	CPP	Power Plant									
UTILITY UNITS	0.1			I			I	I			
	SWI	Sea Water Intake	m3	0.2							
		Cooling Water System	m3	0.2					 		
		Service and Raw Water		0.2				I_			
		Demi Water									
		Boiler Feed Water									
		Fire Water and Fire Fighting									
		Steam System									
		Condensate Recovery System				include	d in BASE LOAD				
		Plant and Instrument Air				incidue					
		Fuel and Natural Gas System									
		·									
		Fuel Oil System Nitrogen Generation and Distribution									
****		Chemicals									
OFF-SITES			ł – – – – – – – – – – – – – – – – – – –								
	FLA	Elaro System									
	TAN	Flare System									
		Tankage and Pumping System									
		Interconnecting System				industa					
		Coke Handling System				include	d in BASE LOAD				
		Sewer Systems									
4500		Trucks Loading Area Buildings, DCS, S/S									



4.5 Power Plant

A simplified power plant is included in the LP models of the 4 refineries, to internally close the steam and power balances, without import/export, as requested in the Reference Document Technical Basis.

The power and steam generation is modelled as boiler(s) producing high pressure steam (HPS at 46 barg, 440°C) followed by condensation steam turbine(s). Part of the HPS steam generated in the boiler(s) is exported to the refinery, while the remaining portion is admitted to steam turbine(s) for power generation. From the turbine, part of the steam is extracted at medium and low pressure levels (HP, MP and LP) to feed the steam networks of the refinery.

The configuration of the simplified power plant is shown in Figure 4-4.

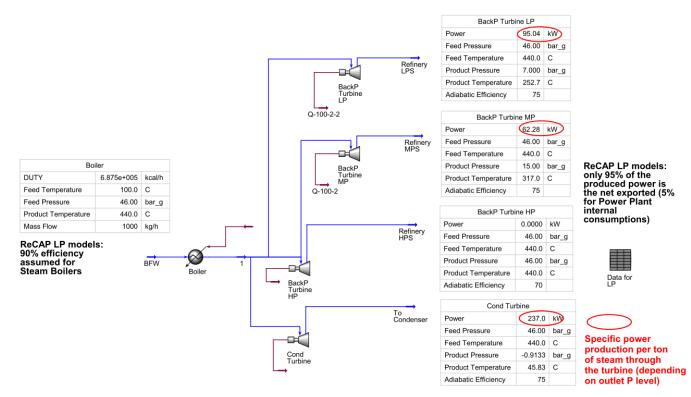


Figure 4-4: Simplified Power Plant configuration considered in the LP models

Moreover, the following assumptions have been made:

- Boiler(s): 90% efficiency,
- Steam Turbines: 75% efficiency (*),
- Net Power Export: 95% of the total generated power (**)
- (*) A relatively low adiabatic efficiency is considered for steam turbines, to take into account some performance worsening due to ageing (efficiency is based on available data for relatively old machines).
- $(^{\star\star})$ $\;$ The remaining 5% is to satisfy the internal consumptions.

Once the refinery balances have been obtained (through the LP models), the configurations of the Power Plant for all the Base Cases have been defined in more detail, as described in the following paragraphs 5.4, 6.4, 7.4 and 8.4. The addition of CO_2 capture plants would have in fact an impact on the refinery steam/power balances, with consequent impacts on the operation/configuration of the power generation unit that need to be addressed as a part of this Study.



In particular, for Base Case 3 and Base Case 4, the Power Plant configuration includes gas turbine(s) in addition to the steam boilers/turbines. Therefore, the LP models relevant to these two cases have been updated to implement the configuration with gas turbine in parallel to steam turbine, in order to calculate more precisely the fuel demand (and consequently the emissions' data) of the Power Plant. Reference is made to paragraphs 7.4 and 8.4 for more details.

4.6 Rate and composition of Flue gases from Fired Heaters

The composition of flue gases from the various fired heaters of the refinery has been calculated depending on the fuel type.

They are reported in the following Table 4-8, Table 4-9 and Table 4-10 respectively for natural gas, sweet refinery offgas and fuel oil.

In all the tables, the combustion of 1 ton of fuel is considered.

It has to be remarked that, in all the refinery balances, the internally produced offgas is not sufficient to satisfy the gaseous fuel demand of the Plant. Therefore, natural gas is imported as a supplementary fuel. The offgas and the natural gas are assumed to be mixed in a centralized refinery fuel gas system and then distributed to all the users of gaseous fuel.

The relative weight of natural gas versus the offgas is dependent on the refinery configuration and it is therefore different in the four Base Cases.

The flowrates of the offgas and natural gas used as refinery fuel are reported in the section "FUEL MIX COMPOSITION" in Table 5-6 (Base Case 1), Table 5-6 (Base Case 2), Table 7-6 (Base Case 3), Table 8-6 (Base Case 4).

For each Base Case, the composition of flue gas from refinery heaters could be calculated as a linear combination of the flue gases generated by the combustion of 1 ton of natural gas (Table 4-8) and by the combustion of 1 ton of sweet refinery offgas (Table 4-9). The flue gas rate from each source could be then calculated from the refinery fuel gas rates reported in Table 5-7, Table 6-7, Table 7-7 and Table 8-7, respectively for Base Case 1 to 4.

In the same tables, the typical temperature levels of flue gases to the stacks are reported for each source. Temperatures are depending on the process service, the presence of heat recovery coils in the convective section (e.g. for steam generation and/or superheating), the presence of air preheating facilities (APH).

In particular, the presence of APH systems is considered typical for heaters designed for a fired duty higher than 20 MMkcal/h (because the payback period for the APH is relatively lower than for small heaters), so resulting in a lower temperature level for the relevant flue gases.



Table 4-8: Flue gas data from natural gas combustion

		N AND EMISSION	o on llool			
		NATURAL GAS				
NPUT DATA						
FUEL GAS CO	MPOSITION, %WT			Н	I2S, PPMV	5
	H2 0					
	СН4 79.22		FIRED 1	DUTY, MM	IKCAL/H	11.103
	C2H4 0					
	C2H6 11.68				SS AIR, %	
	C3H6 0		WA	ER IN AI	R, KG/KG	0.012300
	C3H8 2.45		NOV (N			150
C4H8 0		NOX (NO2), MG/NM3 DRY 150 CO, MG/NM3 DRY 50				
C4H10 0.32 C5H12 0.04		502	CONVERTI			
	N2 1.39	502	CONVERIN		505, /0 w I	5.070
	CO 0					
	CO2 4.9					
	LCULATIONS					
	MOLECULAR WEIGHT	17 97		FLOW/PA'	TE, KG/H	1000.0
1	NHV, KCAL/KG				т L, NO/ П	1000.0
		11100				
AIR CALCULA						
F	LOWRATE DRY, KG/H	18294.89	FLOW	RATE W	ET. KG/H	18519.92
	, ,					
FL	OWRATE DRY, NM3/H	14218.50	FLOWF	ATE WE	Г, NM3/Н	14498.71
FL	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG	14218.50 18.29	FLOWF	ATE WE		14498.71
FL	OWRATE DRY, NM3/H	14218.50 18.29	FLOWF	ATE WE	Г, NM3/Н	14498.71
FL FLOWRA	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG	14218.50 18.29	FLOWF	ATE WE	Г, NM3/Н	14498.71
FL FLOWRA	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT	14218.50 18.29	FLOWF ARIA V	ATE WE	Г, NM3/Н	14498.71 18.52
FL FLOWRA	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS	14218.50 18.29 225	FLOWF ARIA V	ATE WET	Г, NM3/H L, KG/KG	14498.71
FL FLOWRA <mark>WET FLUE G</mark> a	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT	14218.50 18.29 225 NM3/H %VOL	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW	14498.71 18.52 PPMV
FLOWRA FLOWRA WET FLUE GA N2 H2O O2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46%	FLOWF ARIA N CO	ATE WET WET/FUE AG/NM3 41.1	F, NM3/H L, KG/KG PPMW 33.3	14498.71 18.52 PPMV 32.9
FL FLOWRA WET FLUE GA N2 H2O O2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55%	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FLOWRA FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033%	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FLOWRA FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 NO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060%	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FL FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO NO2 SO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.55 0.0060% 0.01 0.0000%	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FLOWRA FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 NO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060%	FLOWF ARIA N CO NOX	ATE WET/FUE VET/FUE IG/NM3 41.1 123.3	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FL FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 NO2 SO2 SO3	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.55 0.0060% 0.01 0.0000%	FLOWF ARIA N CO NOX	ATE WET/FUE WET/FUE IG/NM3 41.1 123.3 1.1	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FL FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO2 SO3 WET FLUE GA	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000%	FLOWF ARIA N CO NOX SOX	ATE WET/FUE WET/FUE IG/NM3 41.1 123.3 1.1	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FL FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO2 SO3 WET FLUE GA	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000%	FLOWF ARIAN NOX SOX	ATE WET/FUE WET/FUE IG/NM3 41.1 123.3 1.1	F, NM3/H L, KG/KG PPMW 33.3 99.8	14498.71 18.52 PPMV 32.9 60.1
FLUE GA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE AS CALCULATIONS KG/H %WT 14045 81.39%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.01 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58%	FLOWF ARIAN NOX SOX 15804 N CO	ATE WET WET/FUE IG/NM3 41.1 123.3 1.1 NM3/H IM3/H	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0
FLUWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE AS CALCULATIONS KG/H %WT 14045 81.39% 555 3.22%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99%	FLOWF ARIAN N CO NOX SOX 15804 N CO NOX	ATE WET WET/FUE IG/NM3 41.1 123.3 1.1 IM3/H IM3/H IG/NM3 50.0 150.0	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0 73.1
FLUWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2 CO2 SO3	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE NS CALCULATIONS KG/H %WT 14045 81.39% 555 3.22% 2654 15.38%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99% 1352 10.41%	FLOWF ARIAN N CO NOX SOX	ATE WET WET/FUE AG/NM3 41.1 123.3 1.1 NM3/H AG/NM3 50.0 150.0 1.4	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9 1.0	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0
FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE SCALCULATIONS KG/H %WT 14045 81.39% 555 3.22% 2654 15.38% 0.65 0.0038%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99% 1352 10.41% 0.52 0.0040%	FLOWF ARIAN CO NOX SOX 15804 N CO NOX SOX	ATE WET WET/FUE AG/NM3 41.1 123.3 1.1 NM3/H AG/NM3 50.0 150.0 1.4 Q O2 EXCL	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9 1.0	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0 73.1
FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE SCALCULATIONS KG/H %WT 14045 81.39% 555 3.22% 2654 15.38% 0.65 0.0038% 1.95 0.0113%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99% 1352 10.41% 0.52 0.0040% 0.95 0.0073%	FLOWF ARIAN CO NOX SOX 15804 N CO NOX SOX CO	ATE WET WET/FUE AG/NM3 41.1 123.3 1.1 NM3/H AG/NM3 50.0 150.0 1.4 Q O2 EXCU 50.0	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9 1.0	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0 73.1
FL FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2 CO2 CO2 CO2 CO2 CO2 CO2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE SCALCULATIONS KG/H %WT 14045 81.39% 555 3.22% 2654 15.38% 0.65 0.0038% 1.95 0.0113% 0.02 0.0001%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99% 1352 10.41% 0.52 0.0040% 0.95 0.0073% 0.01 0.0000%	FLOWF ARIAN CO NOX SOX 15804 M CO NOX SOX CO NOX	ATE WET WET/FUE IG/NM3 41.1 123.3 1.1 IL I I I I I I I I I I I I I I I I I I	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9 1.0	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0 73.1
FLOWRA WET FLUE GA N2 H2O O2 CO2 CO2 CO2 SO2 SO2 SO3 WET FLUE GA DRY FLUE GA N2 O2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2 CO2	OWRATE DRY, NM3/H TE DRY/FUEL, KG/KG HUMIDITY, KG/H AS CALCULATIONS KG/H %WT 14045 71.95% 2263 11.60% 555 2.84% 2654 13.59% 0.65 0.0033% 1.95 0.0100% 0.02 0.0001% 0.00 0.0000% AS FLOWRATE SCALCULATIONS KG/H %WT 14045 81.39% 555 3.22% 2654 15.38% 0.65 0.0038% 1.95 0.0113%	14218.50 18.29 225 NM3/H %VOL 11243 71.14% 2818 17.83% 389 2.46% 1352 8.55% 0.52 0.0033% 0.95 0.0060% 0.01 0.0000% 0.00 0.0000% 19520 KG/H NM3/H %VOL 11243 86.58% 389 2.99% 1352 10.41% 0.52 0.0040% 0.95 0.0073%	FLOWF ARIAN CO NOX SOX 15804 N CO NOX SOX CO	ATE WET WET/FUE AG/NM3 41.1 123.3 1.1 NM3/H AG/NM3 50.0 150.0 1.4 Q O2 EXCU 50.0	F, NM3/H L, KG/KG PPMW 33.3 99.8 0.9 PPMW 37.6 112.9 1.0	14498.71 18.52 PPMV 32.9 60.1 0.4 PPMV 40.0 73.1

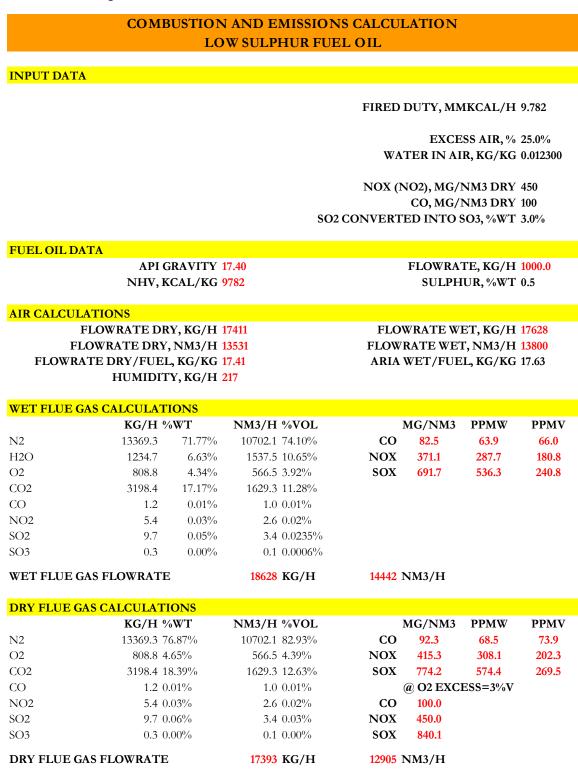


Table 4-9: Flue gas from refinery offgas combustion

	0011200110	IN AIND E	MISSION	S CALCU	LATION		
	SWEET REFINE	RY OFFGA	AS (AVERA	GE COM	POSITIC	N)	
NPUT DAT	'A						
UEL GAS C	COMPOSITION, %WT				H	I2S, PPMV	50
	H2 8						
	СН4 12			FIRED	DUTY, MN	IKCAL/H	12.579
	C2H4 0						
	C2H6 18				EXCE	SS AIR, %	15.0%
	СЗН6 0			WA	TER IN AI	R, KG/KG	0.0123
	СЗН8 24						
	C4H8 0			NOX (1	NO2), MG/		
	C4H10 38				• •	NM3 DRY	
	C5H12 0		SO2	CONVERT	ED INTO S	803, %WT	5.0%
	N2 0						
	CO 0						
	CO2 0						
UEL GAS C	ALCULATIONS						
	MOLECULAR WEIGHT	15.27			FLOWRA	TE, KG/H	1000.0
	NHV, KCAL/KG					, 2, 1	
	, , , , -						
IR CALCU	LATIONS						
	FLOWRATE DRY, KG/H	19875.88		FLO	WRATE W	ET, KG/H	20120.36
F	LOWRATE DRY, NM3/H				RATE WE		
	ATE DRY/FUEL, KG/KG				WET/FUE	•	
					-		
	HUMIDITY, KG/H	244					
		244					
VET FLUE	GAS CALCULATIONS		9/ W.O.I				
	GAS CALCULATIONS KG/H %WT	NM3/H			MG/NM3	PPMW	
12	GAS CALCULATIONS KG/H %WT 15244 72.18%	NM3/H 12203	71.02%	CO	40.8	33.2	32.7
12 12O	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03%	NM3/H 12203 3164	71.02% 18.41%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
V2 12O 02	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86%	NM3/H 12203 3164 422	71.02% 18.41% 2.46%	CO	40.8	33.2	32.7
N2 12O D2 CO2	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92%	NM3/H 12203 3164 422 1391	71.02% 18.41% 2.46% 8.09%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
V2 H2O D2 CO2 CO	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033%	NM3/H 12203 3164 422 1391 0.56	71.02% 18.41% 2.46% 8.09% 0.0033%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
V2 I2O D2 CO2 CO VO2	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100%	NM3/H 12203 3164 422 1391 0.56 1.02	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
V2 12O D2 CO2 CO VO2 O2	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
12 120 02 02 00 102 02	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060%	CO NOX	40.8 122.4	33.2 99.6	32.7 59.6
42 12O 02 202 202 20 20 20 20 20 20 20 20 3	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004%	CO NOX SOX	40.8 122.4	33.2 99.6	32.7 59.6
12 120 22 30 30 30 30 20 3 3 3 3 3 3 3 3 3 3	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0000% KG/H	CO NOX SOX	40.8 122.4 12.3	33.2 99.6	32.7 59.6
V2 12O 02 02 02 02 03 VET FLUE (GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0000% KG/H	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3	33.2 99.6	32.7 59.6 4.3
12 12O 22 202 20 20 20 20 20 3 VET FLUE (DRY FLUE (GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0000% KG/H	CO NOX SOX	40.8 122.4 12.3 NM3/H	33.2 99.6 10.0	32.7 59.6 4.3
12 12O 22 202 20 20 20 20 20 3 VET FLUE (DRY FLUE (22	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3	33.2 99.6 10.0 PPMW	32.7 59.6 4.3 PPMV
V2 12O 22 202 202 20 202 03 VET FLUE (DRY FLUE (V2 22	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H %VOL 87.05%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0	33.2 99.6 10.0 PPMW 37.7	32.7 59.6 4.3 PPMV 40.0
12 120 22 302 302 302 02 03 VET FLUE (DRY FLUE (12 32 32 32 32 32	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422 1391	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H 87.05% 3.01%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	32.7 59.6 4.3 PPMV 40.0 73.1
V2 12O 02 02 02 02 03 VET FLUE (GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25% 2730 14.69%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 21120 NM3/H 12203 422 1391 0.56	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H %VOL 87.05% 3.01% 9.92%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0 15.1	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	32.7 59.6 4.3 PPMV 40.0 73.1
12 120 22 202 202 202 203 VET FLUE (DRY FLUE (12 22 22 22 20 23 20 20 20 20 20 20 20 20 20 20 20 20 20	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25% 2730 14.69% 0.70 0.0038%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422 1391 0.56 1.02	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0000% KG/H %VOL 87.05% 3.01% 9.92% 0.0040%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0 15.1 @ O2 EXC	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	32.7 59.6 4.3 PPMV 40.0 73.1
12 120 22 302 302 302 302 303 VET FLUE (DRY FLUE (12 302 302 302 302 302 302 302 302 302 30	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25% 2730 14.69% 0.70 0.0038% 2.10 0.0113%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422 1391 0.56 1.02 0.07	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H %VOL 87.05% 3.01% 9.92% 0.0040% 0.0073%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0 15.1 @ O2 EXC 50.0	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	59.6 4.3 PPMV 40.0 73.1
V2 12O 22 202 202 203 VET FLUE (0 VET FLUE (0 V2 22 20 22 20 20 20 20 20 20 20 20 20 20	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25% 2730 14.69% 0.70 0.0038% 2.10 0.0113% 0.20 0.0011%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422 1391 0.56 1.02 0.07 0.00	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H %VOL 87.05% 3.01% 9.92% 0.0040% 0.0073% 0.0005% 0.0000%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0 150.0 15.1 @ O2 EXC 50.0 150.1 15.1	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	32.7 59.6 4.3 PPMV 40.0 73.1
12 12O 22 102 102 102 02 03 7ET FLUE (PRY FLUE (12 12 12 12 12 12 12 12 12 12 12 12 12	GAS CALCULATIONS KG/H %WT 15244 72.18% 2541 12.03% 603 2.86% 2730 12.92% 0.70 0.0033% 2.10 0.0100% 0.20 0.0010% 0.01 0.0000% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 15244 82.05% 603 3.25% 2730 14.69% 0.70 0.0038% 2.10 0.0113% 0.20 0.0011%	NM3/H 12203 3164 422 1391 0.56 1.02 0.07 0.00 21120 NM3/H 12203 422 1391 0.56 1.02 0.07 0.00	71.02% 18.41% 2.46% 8.09% 0.0033% 0.0060% 0.0004% 0.0000% KG/H %VOL 87.05% 3.01% 9.92% 0.0040% 0.0073% 0.0005%	CO NOX SOX	40.8 122.4 12.3 NM3/H MG/NM3 50.0 150.0 150.0 15.1 @ O2 EXC 50.0 150.1	33.2 99.6 10.0 PPMW 37.7 113.2 11.4	32.7 59.6 4.3 PPMV 40.0 73.1



Table 4-10: Flue gas from fuel oil combustion





4.7 Syngas and Flue Gas from Steam Methane Reformer

A Steam Methane Reformer unit (Unit 1200 – SMR) is present in 3 out of 4 refinery Base Cases, to satisfy the hydrogen demand of several process units.

Typical heat and material balances have been developed by Amec Foster Wheeler for a SMR operating to produce 20,000 Nm³/h hydrogen (design capacity 30,000 Nm³/h), in line with the capacity of SMR of Base Case 2 (see also paragraph 6.1).

Table 4-11 includes flowrate, conditions and composition of the Syngas upstream the Pressure Swing Absorption (PSA). Reference is made to the sketch in Figure 4-5.

Since this Syngas stream is relatively rich in CO_2 and at a relatively high pressure, it could be attractive to capture CO_2 from it. Syngas flowrates in Base Case 3 and Base Case 4 could be calculated on a pro-rate basis for the higher capacities.

, 0		
Stream		3
Description		PSA Inlet (Syngas)
Temperature	°C	35
Pressure	MPa	2.67
Molar Flow	kmol/h	1349.57
Mass Flow	kg/h	14261.17
Composition		
CO2	mol/mol	0.1627
со	mol/mol	0.0464
Hydrogen	mol/mol	0.7563
H2S	mol/mol	0.0000
Ammonia	mol/mol	0.0000
Nitrogen	mol/mol	0.0024
Oxygen	mol/mol	0.0020
Methane	mol/mol	0.0000
Ethane	mol/mol	0.0302
Propane	mol/mol	0.0000
n-Butane	mol/mol	0.0000
i-Butane	mol/mol	0.0000
i-Butene	mol/mol	0.0000
n-Pentane	mol/mol	0.0000
i-Pentane	mol/mol	0.0000
n-Hexane	mol/mol	0.1627
C6+	mol/mol	0.0464
H2O	mol/mol	0.7563
Contaminants:		
NOx	mg/Nm3	

Table 4-11: Syngas data for Steam Methane Reformer (20,000 Nm³/h operating capacity)

(*) 30 mg/Nm³ max



As an alternative, for the application of the post-combustion CO_2 capture cases, Table 4-12 includes rate and composition of the flue gases generated by the combustion of 2.32 tons of tail gas, which correspond to the tail gas rate generated by 1 ton of natural gas used as feed to SMR.

Total rate and average composition of the flue gas sent to SMR stack could be then calculated as a linear combination of the flue gases generated by 1 ton of feed and 1 ton of fuel, using the rates of feed and fuel to SMR reported in Table 5-7, Table 6-7, Table 7-7 and Table 8-7, respectively for Base Case 1 to 4.

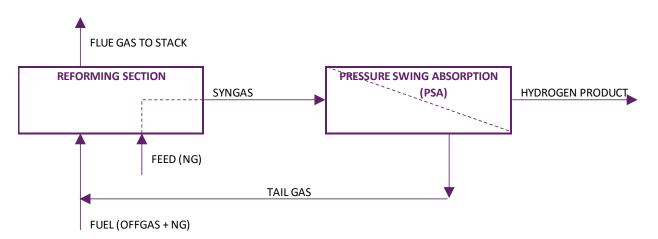


Figure 4-5: Steam Methane Reformer simplified representation



Table 4-12: Flue gas from PSA tail gas combustion

	COMBUSTIO	N AND EMISSION	S CALCUI	LATION		
		PSA TAIL GAS				
NPUT DAT.	A					
FUEL GAS C	OMPOSITION, %WT			H	I2S, PPMV	50
	H2 2.0					
	СН4 5.2		FIRED	DUTY, MN	/KCAL/H	3.576
	C2H4 0					
	С2Н6 0			EXCE	SS AIR, %	15.0%
	СЗН6 0		WA	TER IN AI	R, KG/KG	0.0123
	СЗН8 0					
	C4H8 0		NOX (1	NO2), MG/	NM3 DRY	150
	C4H10 0			CO, MG/	NM3 DRY	50
	С5Н12 0	SO2	CONVERT	ED INTO	SO3, %WT	5.0%
	N2 0.6					
	CO 14.1					
	CO2 77.6					
	H2O 0.5					
FUEL GAS C	ALCULATIONS					
	MOLECULAR WEIGHT	27.59		FLOWRA	TE, KG/H	2320.1
	NHV, KCAL/KG				, -,	
AIR CALCUI	LATIONS					
	FLOWRATE DRY, KG/H	5162.00	FLO'	WRATE W	ET, KG/H	5225.49
F	LOWRATE DRY, NM3/H	4011.83	FLOW	RATE WE	Г, NM3/H	4090.89
FLOWR	ATE DRY/FUEL, KG/KG	2.22	ARIA	WET/FUE	L, KG/KG	2.25
	HUMIDITY, KG/H	63				
WET FLUE (GAS CALCULATIONS					
	KG/H %WT	NM3/H %VOL		MG/NM3	PPMW	PPMV
N2	3973 52.58%	3180 56.80%	CO	41.5	30.7	
H2O	765 10.13%	953 17.02%	NOV	124.5	00.0	33.2
02		JJJ 17.0270	NOX		92.2	33.2 60.7
	157 2.07%	110 1.96%	SOX	48.5	92.2 36.0	
	157 2.07% 2661 35.21%			48.5		60.7
002		110 1.96%		48.5		60.7
CO2 CO	2661 35.21%	110 1.96% 1355 24.21%		48.5		60.7
CO2 CO NO2	2661 35.21% 0.23 0.0031%	110 1.96% 1355 24.21% 0.19 0.0033%		48.5		60.7
CO2 CO NO2 SO2	2661 35.21% 0.23 0.0031% 0.70 0.0092%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061%		48.5		60.7
CO2 CO NO2 6O2 6O3	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016%	SOX	48.5 NM3/H		60.7
CO2 CO NO2 SO2 SO3 WET FLUE (2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001%	SOX			60.7
CO2 CO NO2 SO2 SO3 WET FLUE (2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001%	SOX 5599 1			60.7 16.8
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS	 110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H 	SOX 5599 1	NM3/H	36.0	60.7 16.8
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (N2	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL	SOX 5599 1	NM3/H MG/NM3	36.0 PPMW	60.7 16.8 PPMV
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (N2 N2	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45%	SOX 5599 2 CO	NM3/H MG/NM3 50.0	36.0 PPMW 34.2	60.7 16.8 PPMV 40.0
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (N2 SO2 CO2	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36%	SOX 5599 T CO NOX SOX	NM3/H MG/NM3 50.0 150.0	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (N2 CO2 CO2 CO2	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE SAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30% 2661 39.18%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36% 1355 29.17%	SOX 5599 T CO NOX SOX	NM3/H MG/NM3 50.0 150.0 58.5	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (DRY FLUE (CO2 CO2 CO NO2	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30% 2661 39.18% 0.23 0.0034%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36% 1355 29.17% 0.19 0.0040%	SOX 5599 CO NOX SOX	NM3/H MG/NM3 50.0 150.0 58.5 @ O2 EXC	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1
CO2 CO NO2 SO2 SO3 WET FLUE (2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30% 2661 39.18% 0.23 0.0034% 0.70 0.0103%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36% 1355 29.17% 0.19 0.0040% 0.34 0.0073%	SOX 5599 2 CO NOX SOX CO	NM3/H MG/NM3 50.0 150.0 58.5 @ O2 EXC 48.3	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1
CO2 CO NO2 SO2 SO3 WET FLUE (DRY FLUE (DRY FLUE (20 CO2 CO2 SO2 SO2 SO3	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30% 2661 39.18% 0.23 0.0034% 0.70 0.0103% 0.26 0.0038% 0.01 0.0002%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36% 1355 29.17% 0.19 0.0040% 0.34 0.0073% 0.09 0.0019% 0.00 0.0001%	SOX 5599 CO NOX SOX CO NOX SOX	NM3/H MG/NM3 50.0 150.0 58.5 @ O2 EXC 48.3 144.9 56.5	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1
202 20 202 03 VET FLUE (DRY FLUE (DRY FLUE (20 20 20 20 20 20 20 20 20 20 20 20 20	2661 35.21% 0.23 0.0031% 0.70 0.0092% 0.26 0.0034% 0.01 0.0002% GAS FLOWRATE GAS CALCULATIONS KG/H %WT 3973 58.50% 157 2.30% 2661 39.18% 0.23 0.0034% 0.70 0.0103% 0.26 0.0038%	110 1.96% 1355 24.21% 0.19 0.0033% 0.34 0.0061% 0.09 0.0016% 0.00 0.0001% 7557 KG/H NM3/H %VOL 3180 68.45% 110 2.36% 1355 29.17% 0.19 0.0040% 0.34 0.0073% 0.09 0.0019%	SOX 5599 CO NOX SOX CO NOX SOX	NM3/H MG/NM3 50.0 150.0 58.5 @ O2 EXC 48.3 144.9	36.0 PPMW 34.2 102.6 40.0	60.7 16.8 PPMV 40.0 73.1



4.8 Flue Gas from Fluid Catalytic Cracking (FCC) unit

A Fluid Catalyitc Cracking unit (Unit 1000 – FCC) is present in 3 out of 4 refinery Base Cases, to convert into valuable distillate (LPG, gasoline and diesel) the Vacuum Gasoil.

In the FCC, the circulating catalyst is continuously regenerated by burning the coke on it. This happens in the Regeneration section, where air is injected to achieve total oxidation of the coke.

The following Table 4-13 shows the compositions of the flue gas leaving the FCC Regenerator.

COMBUSTION AND EMISSIONS CALCULATION FCC COKE REV.1 COKE FLOWRATE, KG/H 1000 NHV, KCAL/KG 9200 WET FLUE GAS CALCULATIONS KG/H %WT NM3/H %VOL MG/NM3 PPMW PPMV N2 9995 66.95% 8001 71.08% CO 0.0 0.0 0.0 H2O NOX 0.0 0.0 0.0 889 5.95% 1126 10.00% O2 370 2.48% 259 2.30% SOX 741.2 558.9 256.5 CO2 3667 24.56% 1868 16.59% 0.0 0.00% CO 0.0 0.00% NO2 0.0 0.00% 0.0 0.00% SO2 7.9 0.05% 2.8 0.02% SO3 0.5 0.00% 0.1 0.00% WET FLUE GAS FLOWRATE 14929 KG/H 11256 NM3/H **DRY FLUE GAS CALCULATIONS** PPMV KG/H %WT NM3/H %VOL MG/NM3 PPMW N2 9995 71.19% 8001 78.98% CO 0.0 0.0 0.0 O2 370 2.63% 259 2.56% NOX 0.0 0.0 0.0 CO2 3667 26.12% 1868 18.44% SOX 823.5 594.3 285.0 (a) O2 EXCESS=3%V CO 0.0 0.00% 0.0 0.00% NO2 0.0 0.00% 0.0 0.00% со 0.0 2.8 0.03% 0.0 SO2 7.9 0.06% NOX 0.1 0.00% 803.7 SO3 0.5 0.00% SOX DRY FLUE GAS FLOWRATE 14039 KG/H 10131 NM3/H

Table 4-13: Flue gas from FCC coke combustion



4.9 Flue Gas from Gas Turbine (GT) and Heat Recovery Steam Generators (HRSG)

As described in the following paragraphs 7.4 and 8.4, the Power Plant in Base Case 3 and Base Case 4 includes Gas Turbine(s) and relevant Het Recovery Steam Generator(s).

The specific rate (per ton of natural gas fed to the gas turbine) and composition of flue gases from the GT+HRSG is reported in the following tables. SOx concentration in the flue gas is not reported, being it far below 5 ppm wt.

	%vol	MW	%wt
		kg/kmol	
CH4	0%	16	0%
C2H6	0%	30	0%
C3H8	0%	44	0%
C4H10	0%	58	0%
C5H12	0%	72	0%
CO2	3.20%	44	5.00%
N2	76.40%	28	74.94%
SO2	0%	32	0%
02	13.40%	32	15.00%
H2	0%	2	0%
H2O	6.10%	18	3.84%
Ar	0.90%	40	1.22%
Total	1	28.6	100%

from GT

From HR	SG		
	%vol	MW	%wt
		kg/kmol	
CH4	0%	16	0%
C2H6	0%	30	0%
C3H8	0%	44	0%
C4H10	0%	58	0%
C5H12	0%	72	0%
CO2	4.87%	44	7.55%
N2	75.10%	28	74.22%
SO2	0%	32	0%
02	9.78%	32	11.04%
H2	0%	2	0%
H2O	9.40%	18	5.98%
Ar	0.86%	40	1.21%
Total	1	28.3	100%

Spec flue gas flowrate [t/t NG to GT]

53.0 t/t NG to GT



5. Base Case 1

Hydro-skimming Refinery - 100,000 BPSD Crude Capacity

The Hydro-skimming refinery is essentially composed of primary distillation units (Atmospheric and Vacuum), a gasoline block (Naphtha Hydrotreater, Splitter, Isomerization and Catalytic Reformer) for the production of on-spec gasolines, a Kerosene Sweetening unit for jet fuel production and middle-distillates Hydro-desulphurization units for the production of automotive diesel, marine diesel and heating oil. The residue from Vacuum distillation unit is partially sold as bitumen and partially sent to Visbreaking Unit, for partial conversion into distillates and viscosity reduction of the residue to comply with fuel oils' specifications.

The Hydrogen Rich Gas from the Heavy Naphtha Catalytic Reformer is compressed, sent to a Pressure Swing Absorber (PSA) module to increase the hydrogen concentration, and finally used for the desulphurization of products. No Steam Methane Reformer is included in the process scheme.

Crude Atmospheric Distillation and Vacuum Distillation are not thermally integrated, since they are considered being built in different phases (i.e. Vacuum Distillation, Vacuum Gasoil Hydrotreater and Visbreaking added in a second phase).

Sea Water is used for condensation and cooling purposes. No cooling towers are installed.

5.1 Refinery Balances

The balances developed for Base Case 1 are reported in the following tables and figures:

- Table 5-1: Base Case 1) Overall material balance
- Table 5-2: Base Case 1) Process units operating and design capacity
- Table 5-3: Base Case 1) Gasoline qualities
- Table 5-4: Base Case 1) Distillate qualities
- Table 5-5: Base Case 1) Fuel oil and bitumen qualities
- Table 5-6: Base Case 1) Main utility balance, fuel mix composition, CO2 emissions
- Figure 5-1: Base Case 1) Block flow diagrams with main material streams
- Table 5-7: Base Case 1) CO2 emissions per unit

REV.7 12/05/2016	ReCAP Project Refinery Balances BASE CASE 1 Hydroskimming refinery, 100,000 BPSD	amec foster wheeler
	OVERALL MATERIAL BALANCE	
PRODUCTS	Annu	al Production, kt/y
LPG		110.7
Petrochemical Naphtha		24.2
Gasoline U95 Europe		614.6
Gasoline U92 USA Export		263.4
Jet fuel		450.0
Road Diesel		1372.9
Marine Diesel		183.0
Heating Oil		274.6
Low Sulphur Fuel Oil		806.2
Medium Sulphur Fuel Oil		0.0
High Sulphur Fuel Oil		518.0
Bitumen		125.0
Sulphur		13.5
	Subtotal	4756.1
RAWMATERIALS	Cor	nsumptions, kt/y
Ekofisk		1272.8
Bonny Light		1226.9
Arabian Light		460.0
Urals Medium		1390.0
Arabian Heavy		139.0
Maya Blend (1)		244.0
MTBE		59.8
Natural Gas		121.8
Biodiesel		86.7
Ethanol		31.9
	Subtotal	5033.0
		kt/y
Fuels and Losses		276.9

Notes

1) Maya Blend consists of 50% wt. Maya crude oil + 50% wt.

REV.7 12/05/2016

ReCAP Project Refinery Balances



BASE CASE 1 Hydroskimming refinery, 100,000 BPSD

PROCESS UNITS OPERATING AND DESIGN CAPACITY

UNIT	Unit of measure	Design Capacity	Operating Capacity	Average Utilization
Crude Distillation Unit	BPSD	100000	100000	100%
Vacuum Distillation Unit	BPSD	35000	32805	94%
Naphtha Hydrotreater	BPSD	23000	21434	93%
Light Naphtha Isomerization	BPSD	8000	7292	91%
Heavy Naphtha Catalytic Reforming	BPSD	15000	13778	92%
Kero Sweetening	BPSD	5000	5000	100%
Kerosene Hydrotreater	BPSD	14000	13594	97%
Diesel Hydrotreater	BPSD	26000	24480	94%
Heavy Gasoil Hydrotreater	BPSD	6000	5610	94%
Visbreaking	BPSD	13000	11997	92%
Sulphur Recovery Unit	t/d Sulphur	55	38	70%

REV 12/05/			ReCAP Project Refinery Balance BASE CASE 1 ning refinery, 10	9S	amec foster wheeler		
EXCESS NAPH	THA	GAS	SOLINE QUALI	<u>TIES</u>			
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent	
NAH	HT HEA	vy naphtha	14,449.82	59.680%	19,369.73	58.000%	
NSCR5		APHTHA ARAB.HEAVY	9,762.35		14,026.36		
		Total	24,212.17	100.000%	33,396.09	100.000%	
Quality			Blending Basis	Value	Min	Max	
RHO	DENSIT	Y, KG/M3	VL	725.00		725.00	
SPM		, PPMW	WT	144.36		500.00	
VPR Unl. Premium	VAPOR	PRESSURE, KPA	VL	28.61		69.00	
VPR	VAPOR		∨L Weight Quantity		Volume Quantity		
VPR Unl. Premium	VAPOR (95) EU				Volume Quantity 3,151.28	Volume Percent	
VPR Unl. Premium Component	VAPOR (95) EU C4 TO M	PRESSURE, KPA	Weight Quantity	Weight Percent	Quantity	Volume Percent	
VPR Unl. Premium Component BU#	(95) EU	PRESSURE, KPA 10GAS/LPG	Weight Quantity	Weight Percent	Quantity 3,151.28	Volume Percent 0.393% 0.047%	
VPR Unl. Premium Component BU# HRF	(95) EU	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100	Weight Quantity 1,823.33 318.85	Weight Percent 0.297% 0.052%	Quantity 3,151.28 376.45	Volume Percent 0.393% 0.047% 53.378%	
VPR Unl. Premium Component BU# HRF R10	(95) EU C4 TO M HEAVY REFORM	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100	Weight Quantity 1,823.33 318.85 355,242.13	Weight Percent 0.297% 0.052% 57.803%	Quantity 3,151.28 376.45 428,518.85	Volume Percent 0.393% 0.047% 53.378% 31.183%	
VPR Unl. Premium Component BU# HRF R10 ISO	(95) EU C4 TO M HEAVY REFORM	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 IATE ASED MTBE	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91	Weight Percent 0.297% 0.052% 57.803% 26.925%	Quantity 3,151.28 376.45 428,518.85 250,337.24	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000%	
VPR Unl. Premium Component BU# HRF R10 ISO MTB	(95) EU C4 TO M HEAVY REFORI ISOMER PURCH/	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 IATE ASED MTBE	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732%	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000%	
VPR Unl. Premium Component BU# HRF R10 ISO MTB	(95) EU C4 TO M HEAVY REFORI ISOMER PURCH/	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 IATE ASED MTBE DL	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192%	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22	69.00 Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 100.000% Max	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH Quality	(95) EU (95) EU (95) EU (95) EU (97) EFOR (97) EFOR (97) ETHANC	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 KATE ASED MTBE DL Total	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO	(95) EU (95) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 IATE ASED MTBE DL	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000%	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH	(95) EU (95) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE ASED MTBE DL Total Y, KG/M3	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM VPR	(95) EU (95) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 CATE ASED MTBE DL Total Y, KG/M3 R, PPMW PRESSURE, KPA	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL WT	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM VPR BEN	(95) EU (95) EU (95) EU (95) EU (95) EU (97) EU (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) EU (97) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 CATE ASED MTBE DL Total Y, KG/M3 R, PPMW PRESSURE, KPA	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL WT VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00 1.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH Quality RHO SPM VPR BEN ARO	(95) EU (95) EU (95) EU (95) EU (95) EU (97) EU (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) ET (97) ED (97) EU (97) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE ASED MTBE DL Total Y, KG/M3 R, PPMW PRESSURE, KPA JE, %V	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL WT VL VL VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00 0.052%	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00 1.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM VPR BEN ARO E50	(95) EU (95) EU C4 TO M HEAVY REFORI ISOMER PURCH/ ETHANC DENSIT SULFUR VAPOR BENZEN AROMA D86 @ 1	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE ASED MTBE DL Total Y, KG/M3 R, PPMW PRESSURE, KPA JE, %V TICS, %V	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL VL VL VL VL VL VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00 0.87 35.00	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min 720.00	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM VPR BEN ARO E50 OXY	(95) EU (95) EU (95) EU (95) EU (95) EU (97) ET (97) ED (97) E	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE ASED MTBE DL Total Y, KG/M3 A, PPMW PRESSURE, KPA JE, %V TICS, %V JS0°C, %V VATES, %V	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL WT VL VL VL VL VL VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00 0.87 35.00 88.24	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min 720.00	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00 15.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM VPR BEN ARO E50 OXY OLE	(95) EU (95) EU C4 TO M HEAVY REFORM ISOMER PURCH/ ETHANC DENSIT SULFUR VAPOR BENZEN AROMA D86 @ 1 OXYGEN OLEFINS	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE ASED MTBE DL Total Y, KG/M3 2, PPMW PRESSURE, KPA JE, %V TICS, %V 50°C, %V VATES, %V S, %V	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00 0.87 35.00 88.24 15.00 0.10	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min 720.00	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 60.00 1.00 60.00 1.00 15.00 18.00	
VPR Unl. Premium Component BU# HRF R10 ISO MTB EOH EOH Quality RHO SPM	(95) EU (95) EU C4 TO M HEAVY REFORM ISOMER PURCH/ ETHANC DENSIT SULFUR VAPOR BENZEN AROMA D86 @ 1 OXYGEN OLEFINS	PRESSURE, KPA IOGAS/LPG REFORMATE MATE 100 ATE 100 ATE ASED MTBE DL Total Y, KG/M3 2, PPMW PRESSURE, KPA JE, %V TICS, %V 50°C, %V VATES, %V S, %V DL, VOI%	Weight Quantity 1,823.33 318.85 355,242.13 165,472.91 59,808.93 31,911.48 614,577.63 Blending Basis VL	Weight Percent 0.297% 0.052% 57.803% 26.925% 9.732% 5.192% 100.000% Value 765.54 1.96 60.00 0.87 35.00 88.24 15.00	Quantity 3,151.28 376.45 428,518.85 250,337.24 80,280.45 40,140.22 802,804.49 Min 720.00	Volume Percent 0.393% 0.047% 53.378% 31.183% 10.000% 5.000% 100.000% Max 775.00 10.00 60.00	

REV 12/05/		fo	nec oster heeler			
Unl. Premium ((02)	<u>GA</u>	SOLINE QUALI	<u>11E5</u>		
Component	(32)		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
BU#	C4 TO MOGAS/LPG		2,319.90	0.881%	4,009.52	1.141%
R10	REFORMATE 100		155,585.29	59.070%	187,678.28	53.428%
ISO	ISOMERATE		105,485.22	40.049%	159,584.29	45.430%
	•	Total	263,390.41	100.000%	351,272.09	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3		VL	749.82	720.00	775.00
SPM	SULFUR, PPMW		WT	0.04		10.00
VPR	VAPOR PRESSURE, KPA		VL	60.00		60.00
BEN	BENZENE, %V		VL	0.87		1.00
ARO	AROMATICS, %V		VL	35.00		35.00
E50	D86 @ 150°C, %V		VL	88.25	75.00	
OXY	OXYGENATES, %V		VL	0.00		15.00
OLE	OLEFINS, %V		VL	0.15		18.00
EOH	ETHANOL, VOI%		VL	0.00		10.00
RON	Research		VL	92.23	92.00	
MON	Motor		VL	85.29	84.00	

REV 12/05/	²⁰¹⁶	ReCAP Project Refinery Balance BASE CASE 1 ming refinery, 10	28	f	amec oster vheeler
		FILLATE QUAL	ITIES		
LPG PRODUCT		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
LG#	LPG POOL	110,702.16	100.000%	197,532.72	100.000%
	Total	110,702.16	100.000%	197,532.72	100.000%
Quality		Blending Basis	Value	Min	Max
SPM	SULFUR, PPMW	WT	5.00		140.00
VPR	VAPOR PRESSURE, KPA	VL	666.23	632.40	887.60
OLW	OLEFINS, %W	WT	0.66		30.00
Jet Fuel EU		Weisha Oversiter	Weight Deveent	Volume	Volume Percent
Component		Weight Quantity	-	Quantity	
KED	HTKERO	227,714.60	50.603%	286,974.92	50.774%
KMCR4	KERO FROM MEROX URALS	173,927.93	38.651%	217,682.01	38.514%
KMCR5	KERO FROM MEROX AR.HVY	16,541.00		20,676.25	3.658%
KMCR6	KERO FROM MEROX MAYA	31,816.48 450,000.00	7.070%	39,870.27 565,203.45	7.054%
_		,			
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	796.17	775.00	840.0
SUL	SULFUR, %W	WT	0.10		0.3
	FLASH POINT, °C (PM, D93)	VL	40.00	38.00	
Diesel EU Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
KED	HT KERO	252,101.78	18.363%	317,708.61	19.339%
DLG	DESULF LGO	1,034,021.97	75.318%	1,226,597.83	
FAM	BIODIESEL	86,744.02	6.318%	98,572.75	
	Total	1,372,867.78	100.000%	1,642,879.20	100.000%
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	835.65	820.00	845.00
	SULFUR, PPMW	WT	9.00		10.0
SPM	001			55.00	
	FLASH POINT, °C (PM, D93)	VL	57.30	55.00	
FLC		VL VL	49.84	46.00	
SPM FLC CIN V04	FLASH POINT, °C (PM, D93)				4.5
FLC CIN	FLASH POINT, °C (PM, D93) CETANE INDEX D4737	VL	49.84	46.00	4.5

REV 12/05,		ReCAP Project Refinery Balances		Refinery Balances		imec
		Hydroskim	BASE CASE 1 ming refinery, 10	0,000 BPSD		oster vheeler
Heating Oil		DIST	TILLATE QUAL	<u>ITIES</u>		
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
KED	HT KER	0	79,786.98	29.059%	100,550.70	31.115%
H1CR1	HGO EK	OFISK	31,094.56	11.325%	35,374.92	10.946%
DLG	DESULF	LGO	53,592.25	19.518%	63,573.25	19.672%
VLG	DESULF	LGO ex VHT	18,870.38	6.873%	22,331.81	6.910%
LVCR2	LVGO B	ONNY	91,229.39	33.226%	101,332.22	31.356%
		Total	274,573.56	100.000%	323,162.89	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSIT	Y, KG/M3	VL	849.64	815.00	860.0
SPM	SULFUR	R, PPMW	WT	1,000.00		1,000.0
FLC	FLASH I	POINT, °C (PM, D93)	VL	55.00	55.00	
CIN	CETANE	INDEX D4737	VL	46.59	40.00	
V04	VISCOS	ITY @ 40°C, CST	WT	3.88	2.00	6.00
MARINE DIESE	EL					
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
KED	HT KER	0	33,234.02	18.156%	41,882.83	19.747%
H1CR2	HGO BC	DNNY	64,781.73	35.390%	71,165.25	33.553%
DLG	DESULF		60,886.90		72,226.45	34.054%
LVCR2	LVGO B	ONNY	24,146.39	13.191%	26,820.38	12.645%
LVCRZ				100 0000/	212.094.91	400.000
LVURZ		Total	183,049.04	100.000%	212,094.91	100.000%
Quality		Total	183,049.04 Blending Basis	100.000%	212,094.91	100.000% Max
Quality		Total Y, KG/M3			,	
Quality RHO	DENSIT		Blending Basis	Value	,	Max 890.00
Quality RHO SPM	DENSIT	Y, KG/M3	Blending Basis	Value 863.05	,	Max
	DENSIT SULFUR FLASH I	Y, KG/M3 R, PPMW	Blending Basis VL WT	Value 863.05 1,000.00	Min	Max 890.00

12/05/	7.7 2016		ReCAP Project Refinery Balance BASE CASE 1 ning refinery, 10	2S	f	amec Toster wheeler
Low Sulphur F	uel	<u>FUEL OII</u>	<u>_ / BITUMEN Q</u>	<u>UALITIES</u>		
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
H1CR1	HGO EKOFISK		26,437.65	2.995%	30,076.96	3.241%
VRCR1	VBRES MIX1		115,004.56	13.030%	120,046.52	
VRCR2	VBRES MIX2		68,795.82	7.794%	66,213.50	
VGCR1	HVGO EKOFISK		154,870.03	17.546%	171,032.61	
VGCR4	HVGO URALS		74,361.17	8.425%	79,958.25	
VGCR2	HVGO BONNY		142,237.41	16.115%	153,223.54	
VHR	RESIDUE ex VHT		261,282.19	29.602%	262,595.16	
LVCR1	LVGO EKOFISK	Total	39,656.75 882,645.59	4.493% 100.000%	44,860.57 928,007.12	
Quality			Blending Basis	Value	Min	Мах
-			-		MIII	-
RHO	DENSITY, KG/M3		VL	951.12		991.00
SUL	SULFUR, %W		WT	0.50	00.00	0.50
FLC	FLASH POINT, °C (P	. ,	VL	156.24	66.00	
V05	VISCOSITY @ 50°C,		WT WT	86.81 3.33		380.00
CCR High Sulphur I	CONRADSON CARB	ON RES, %W		0.00		1 10.00
		<u>UN RES, %W</u>	Weight Quantity		Volume	
High Sulphur F		<u>UN RES, %W</u>			Volume Quantity 17,826.28	Volume Percent
High Sulphur F Component	Fuel	UN RES, %W	Weight Quantity	Weight Percent	Quantity	Volume Percent 3.327%
High Sulphur F Component H1CR3 H1CR4	Fuel	UN RES, %W	Weight Quantity 16,008.00	Weight Percent 3.090%	Quantity 17,826.28	Volume Percent 3.327% 4.827%
High Sulphur F Component H1CR3	Fuel HGO ARB. LIGHT HGO URALS	UN RES, %W	Weight Quantity 16,008.00 23,094.34	Weight Percent 3.090% 4.458%	Quantity 17,826.28 25,861.53	Volume Percent 3.327% 4.827% 0.813%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR3 LVCR4 LVCR5	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS	UN RES, %W	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR3 LVCR4 LVCR5	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY		Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA		Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000%	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6	HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY		Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RHO	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3	Total	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50%
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W	Total M, D93)	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W FLASH POINT, °C (P	Total M, D93) CST	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT VL	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15 158.79	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50 380.00
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC V05	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W FLASH POINT, °C (P VISCOSITY @ 50°C,	Total M, D93) CST	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT VL WT	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15 158.79 380.00	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC V05 CCR BITUMEN	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W FLASH POINT, °C (P VISCOSITY @ 50°C,	Total M, D93) CST	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT VL WT	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15 158.79 380.00 12.51	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00 60.00 Volume	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50 380.00 18.00
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC V05 CCR BITUMEN	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W FLASH POINT, °C (P VISCOSITY @ 50°C,	Total M, D93) CST	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT VL WT WT WT	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15 158.79 380.00 12.51	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00 60.00	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50 380.00 18.00
High Sulphur F Component H1CR3 H1CR4 H1CR5 H1CR6 VRCR3 VRCR4 LVCR3 LVCR4 LVCR5 LVCR6 Quality RH0 SUL FLC V05 CCR BITUMEN Component	Fuel HGO ARB. LIGHT HGO URALS HGO ARB.HEAVY HGO MAYA VBRES MIX3 VBRES MIX4 LVGO ARAB.LIGHT LVGO URALS LVGO ARB.HEAVY LVGO MAYA DENSITY, KG/M3 SULFUR, %W FLASH POINT, °C (P VISCOSITY @ 50°C, CONRADSON CARB	Total M, D93) CST	Weight Quantity 16,008.00 23,094.34 3,933.70 7,783.33 74,922.68 241,964.96 32,957.71 95,065.69 7,678.80 14,588.55 517,997.77 Blending Basis VL WT WT WT WT WT WT WT WT	Weight Percent 3.090% 4.458% 0.759% 1.503% 14.464% 46.712% 6.363% 18.353% 1.482% 2.816% 100.000% Value 966.81 3.15 158.79 380.00 12.51 Weight Percent	Quantity 17,826.28 25,861.53 4,356.26 8,595.61 75,148.13 236,756.32 36,566.86 106,147.48 8,454.04 16,070.23 535,782.74 Min 1.00 60.00 Volume Quantity	Volume Percent 3.327% 4.827% 0.813% 1.604% 14.026% 44.189% 6.825% 19.812% 1.578% 2.999% 100.000% Max 991.00 3.50 380.00 18.00 Volume Percent 39.754%

1

REV.7 12/05/2016	Ну	ReCAP Project Refinery Balances BASE CASE 1 droskimming refinery, 100,000 BPSD			amec foster wheeler		er
		<u>Main u</u>	TILITY BALA	NCE			
	FUEL	POWER	HP STEAM	MP STEAM	LP STEAM	COOLING WATER (2)	RAW WATER
	Gcal/h	kW	tons/h	tons/h	tons/h	m3/h	m3/h
MAIN PROCESS UNITS	155	11800	13	38	59	4920	
BASE LOAD	400	15000	10	20	20	4400	
	183	-28345	-23	-58	-79	4106	
SEA WATER SYSTEM		1545				-9026	
				•	•	0	100
тота	220						
TOTAL	338 t/h		0	0 TION	0		
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3)	<i>t/</i> h 7.0 9.1	FUEL M kt/y 58.8 76.4	IX COMPOSI wt% 23% 30%				
TOTAL REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) NATURAL GAS TOTAL	t/h 7.0 9.1 14.5	FUEL M kt/y 58.8 76.4 121.8	IX COMPOSI wt% 23%				
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3)	<i>t/</i> h 7.0 9.1	FUEL M kt/y 58.8 76.4 121.8 256.9	IX COMPOSI wt% 23% 30% 47%	<u>TION</u>			
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) NATURAL GAS	t/h 7.0 9.1 14.5 30.6	FUEL M kt/y 58.8 76.4 121.8 256.9	IX COMPOSI wt% 23% 30%	<u>TION</u>			
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) NATURAL GAS TOTAL	t/h 7.0 9.1 14.5 30.6	FUEL M kt/y 58.8 76.4 121.8 256.9	IX COMPOSI wt% 23% 30% 47%	<u>TION</u>			
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) NATURAL GAS TOTAL From FG/NG combustion	t/h 7.0 9.1 14.5 30.6 t/h 57.7	FUEL M kt/y 58.8 76.4 121.8 256.9	IX COMPOSI wt% 23% 30% 47%	<u>TION</u>			
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) NATURAL GAS TOTAL	t/h 7.0 9.1 14.5 30.6	FUEL M kt/y 58.8 76.4 121.8 256.9	IX COMPOSI wt% 23% 30% 47%	<u>TION</u>			

3) LSFO is burnt in CDU, VDU and VBU heaters

REV.7 12/05/2016

ReCAP Project

Overall Refinery Balance

BASE CASE 1

Hydroskimming Refinery, 100,000 BPSD

BLOCK FLOW DIAGRAM

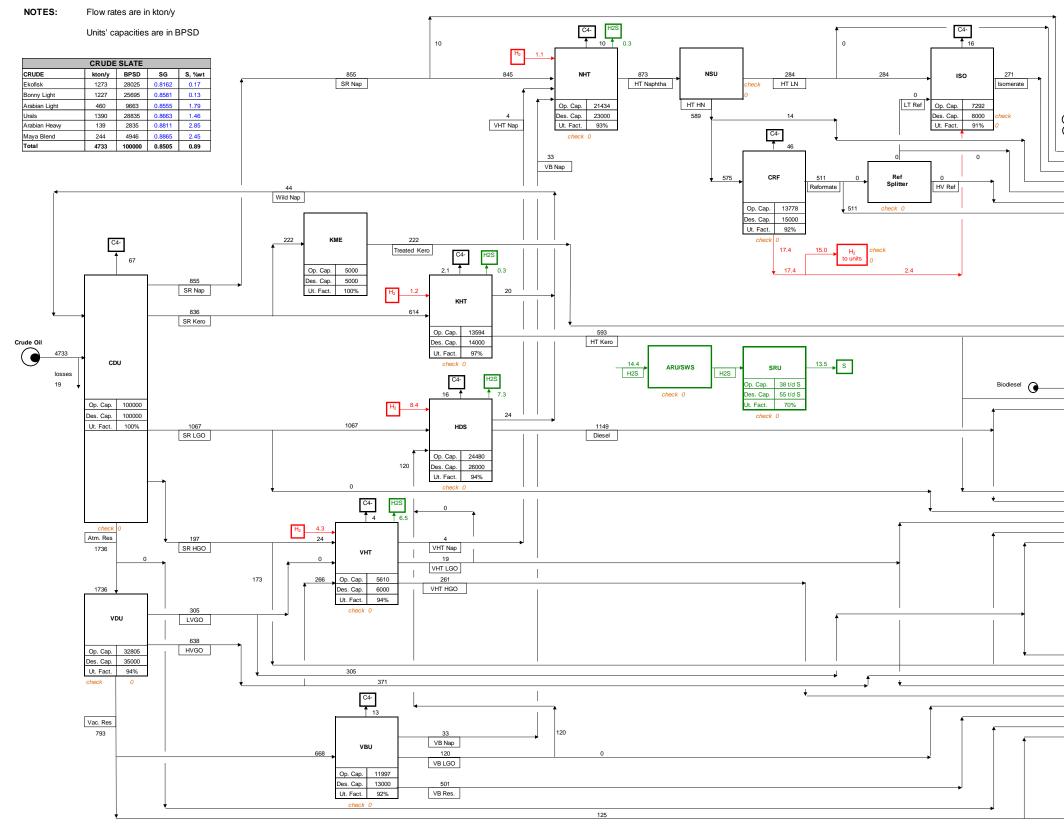


Figure 5-1: Base Case 1) Block flow diagrams with main material streams

	LPG
Propane	25
Butane	85
Total prod.	111
To fuel	0
Sales	111

		U 95-EU	U 92-US	Excess Naph.	тот
	MTBE	60	0	0	60
X	Ethanol	32	0	0	32
0	Butanes	2	2	0	4
	SR Naphtha	0	0	10	10
	HT Light Naphtha	0	0	0	0
	Isomerate	165	105	0	271
	HT Heavy Naphtha	0	0	14	14
	LT Reformate	0	0	0	0
	HV Reformate	0	0	0	0
	Reformate	355	156	0	511
,					
	Sales	615	263	24	902

Jet Fuel
222
228
450
Diesel
87
252
1034

	Heating Oil	Mar. Dies.	тот
HT Kero	80	33	113
Diesel	54	61	114
SR LGO	0	0	0
VHT LGO	19	0	19
SR HGO	31	65	96
SR LVGO	91	24	115
Sales	275	183	458

.

LSFO MSFO HSFO тот SR LVGO SR HGO SR HVGO 190 77 371 40 150 0 26 51 371 0 VHT LGO 0 0 0 VHT HGO 261 0 261 0 VB LGO 0 0 0 0 501 VB Residue 184 317 Atm. Residue 0 0 0 0 Vac. Residue 0 0 0 0 Total prod. 883 518 1401 0 To RFO 76 76 806 0 518 1324

	Bitumen		Sulphur
Vac. Res.	125	Sulphur	13
Sales	125	Sales	13

REV.7 12/05/2016

ReCAP Project 1-BD-0839A

CO2 EMISSIONS PER UNIT - BASE CASE 1

					PROCESS	UNITS								
	UNIT		Unit of measure	Design Capacity	Operating Fuel Consumption [t/h]		Operating CO ₂ Emission [t/h]		% on Total	CO ₂ concentr. Of	Operating	Note		
			Unit of measure	Design Capacity	Fuel Gas	Fuel Oil	Coke	Fuel Gas	Fuel Oil	Coke	CO_2 Emission	vol %	Temperature [°C]	(1)
0100	CDU	Crude Distillation Unit	BPSD	100000	-	7.4	-	-	23.6	-	27.2%	11.3%	200 ÷ 220	
0300	NHT	Naphtha Hydrotreater	BPSD	23000	0.3	-	-	0.8	-	-	0.9%	8.4%	400 + 450	
0350	NSU	Naphtha Splitter Unit	BPSD	23000	0.4	-	-	1.0	-	-	1.1%	8.4%	420 ÷ 450	(2)
0500	CRF	Catalytic Reforming	BPSD	15000	3.3	-	-	8.9	-	-	10.3%	8.4%	180 ÷ 190	
0600	KHT	Kero HDS	BPSD	14000	0.2	-	-	0.6	-	-	0.7%	8.4%	420 ÷ 450	
0700	HDS	Gasoil HDS	BPSD	26000	1.1	-	-	3.0	-	-	3.5%	8.4%	420 ÷ 450	
0800	VHT	Vacuum Gasoil Hydrotreater	BPSD	6000	0.4	-	-	1.0	-	-	1.1%	8.4%	420 ÷ 450	
1100	VDU	Vacuum Distillation Unit	BPSD	35000	-	1.2	-	-	4.0	-	4.6%	11.3%	380 ÷ 400	
1500	VBU	Visbreaking Unit	BPSD	13000	-	0.5	-	-	1.5	-	1.8%	11.3%	380 ÷ 400	
						Sub Tota	Process Units		44.4		51.1%			-
					AUXILIAR									
2200	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	55	0.005	-	-	0.0	-	-	0.0%	< 8%	380 ÷ 400	T
	L	· · · · · · · · · · · · · · · · · · ·			L	Sub Tota	I Auxiliary Units		0.01	•	0.0%		I	
					POWER									
2500	POW	Power Plant	kW	40000	15.8	-	-	42.4	-	-	48.8%	8.4%	130 ÷ 140	T
	•			•		Sub To	tal Power Units		42.4	•	48.8%			
									86.8		100%	1		

TOTAL CO ₂ EMISSION		86.8		
	66%	34%	0%	

Notes

(1) Fuel gas is a mixture of refinery fuel gas (33%) and imported natural gas (67%).(2) Naphtha Hydrotreater and Naphtha Splitter heaters (units 0300 and 0350) have a common stack.

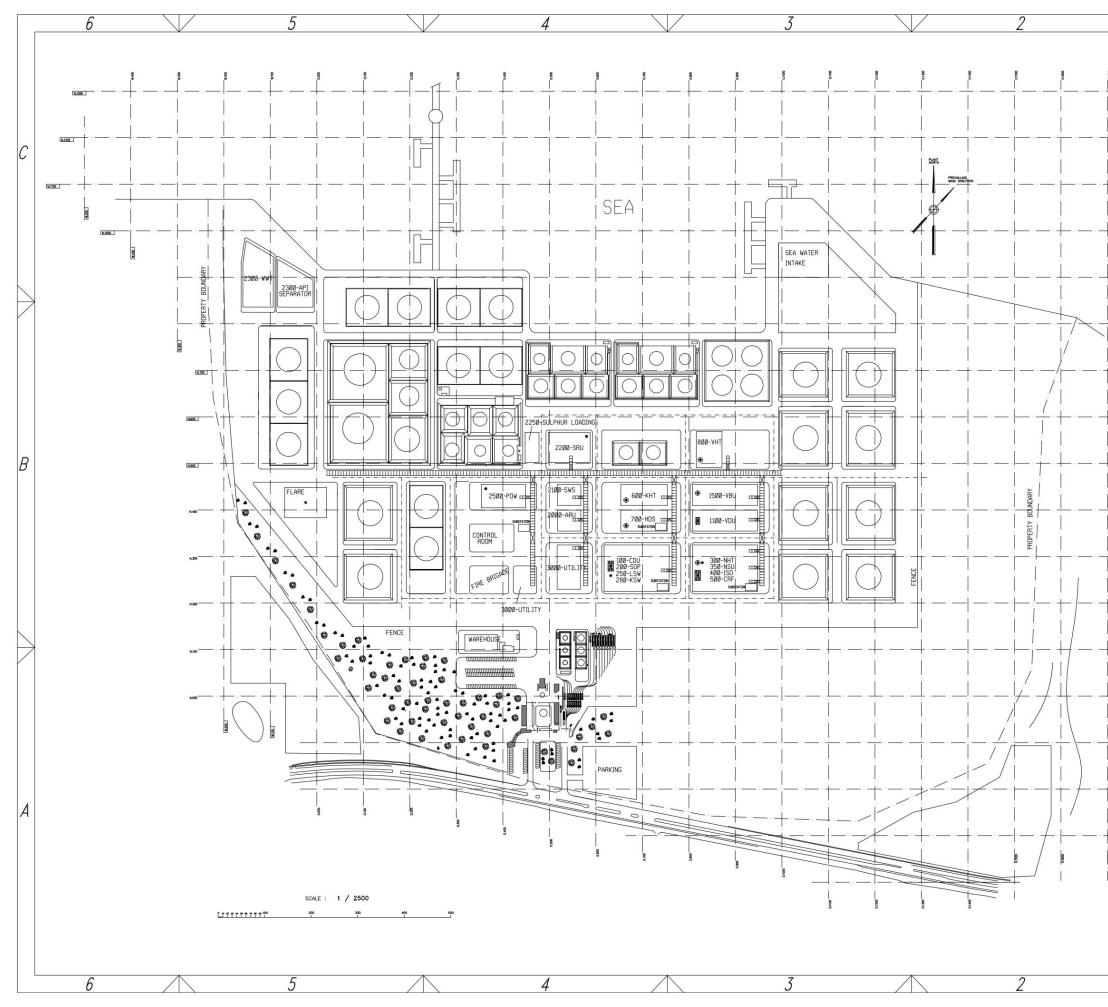


	100%
-	



5.2 Refinery Layout

The layout of the hydro-skimming refinery has been developed in analogy with some real plants of similar size and complexity.



			1		
			UNIT LIST		
	UN	IT	DESCRIPTION		
80.130		100	CRUDE DISTILLATION (CDU)		
N1300		200	SATURATED GAS PLANT (SGP)		
0.000		250	LPG SWEETENING (LSW)		
		28Ø	KERO SWEETENING (KSW)		
		300	NAPHTHA HYDROTREATER (NHT)		
N.1200	ITS	350	NAPHTHA SPLITTER (NSU)		\sim
	NN SS	400	ISOMERIZATION (ISO)		C
	PROCESS UNITS	500	CATALYTIC REFORMING (CRF)		
N.1100		600	KERO HDS (KHT))		
		700	GASOIL HDS (HDS)		
		800	VACUUM GASOIL HYDROTREATER (VHT)		
		1100	VACUUM DISTILLATION (VDU)		
		1500	VISBREAKER UNIT (VBU)		
		2000	AMINE WASHING AND REGENERATION (ARU)		
N.900		2100	SOUR WATER STRIPPER (SWS)		
	UNITS	2200	SULPHUR RECOVERY (SRU)		
	AUXILIARY UNITS		TAIL GAS TREATMENT		$\left(- \right)$
	AUXIL	2250	SULPHUR LOADING		
		2300	WASTE WATER TREATMENT (WWT)		
			API SEPARATOR		
la yann	POWER	2500	POWER PLANT (POW)		
N.700	8 N				
		3000	UTILITY UNITS		
		4000	OFF SITES UNITS		
N.600					
					В
N.400					
-					
					\backslash
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	COO REV.	9/11/1 DATE	DESCRIPTION	P.V. S.T. M.CS. BY CHD APP.	
			REVISIONS	APPROVED FOR CONSTRUCTION	
		nec	foster wheeler	DWG. REV. DATE	
	an			SIGNATURE	i 1
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	an		6	SUPPLIER	
				SUPPLIER CONTRACT Nº 1-BD-0839A	
			BASE CASE 1 E HYDROSKIMMING REFINERY	SUPPLIER CONTRACT N 1-BD-0839A CLIENT DWG N* SCALE 1:2500	
		SIMPL	BASE CASE 1 E HYDROSKIMMING REFINERY 100,000 BPSD WEDAL DLOT DLAN	SUPPLER CONTRACT: IN 1-BD-0839A CLIENT DWG N° SCALE BHEET OF FWIDWG N° REV.	
		SIMPL	BASE CASE 1 E HYDROSKIMMING REFINERY 100,000 BPSD INERAL PLOT PLAN 1	SUPPLER CONTRACT N 1-BD-0839A GLIENT DWG N* SCALE SHEET OF	



5.3 Main Utility Networks

The main utility balances have been reported on block flow diagrams, reflecting the planimetric arrangement of the process units and utility blocks.

In particular, the following networks' sketches have been developed:

- Figure 5-3: Base Case 1) Electricity network
- Figure 5-4: Base Case 1) Steam networks
- Figure 5-5: Base Case 1) Cooling water network
- Figure 5-6: Base Case 1) Fuel Gas/Offgas networks
- Figure 5-7: Base Case 1) Fuel oil network

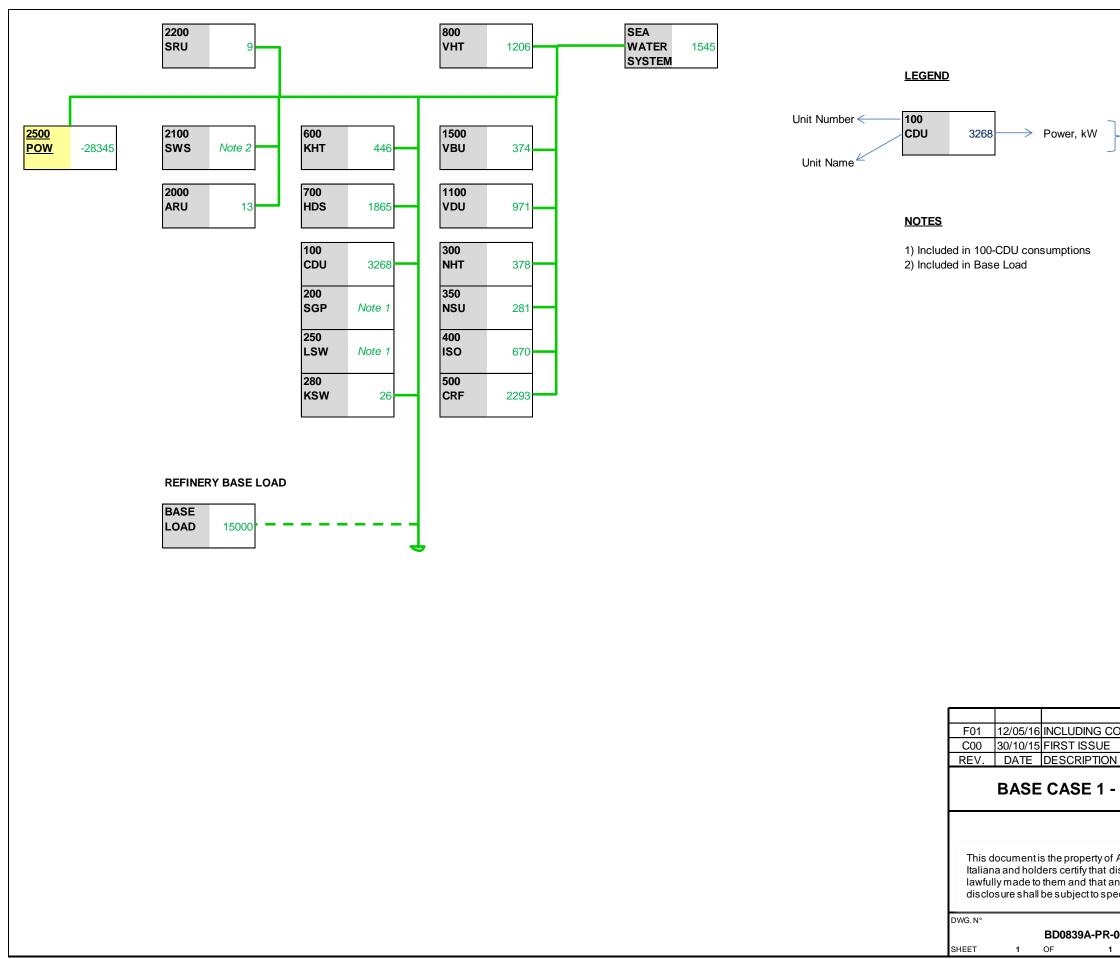
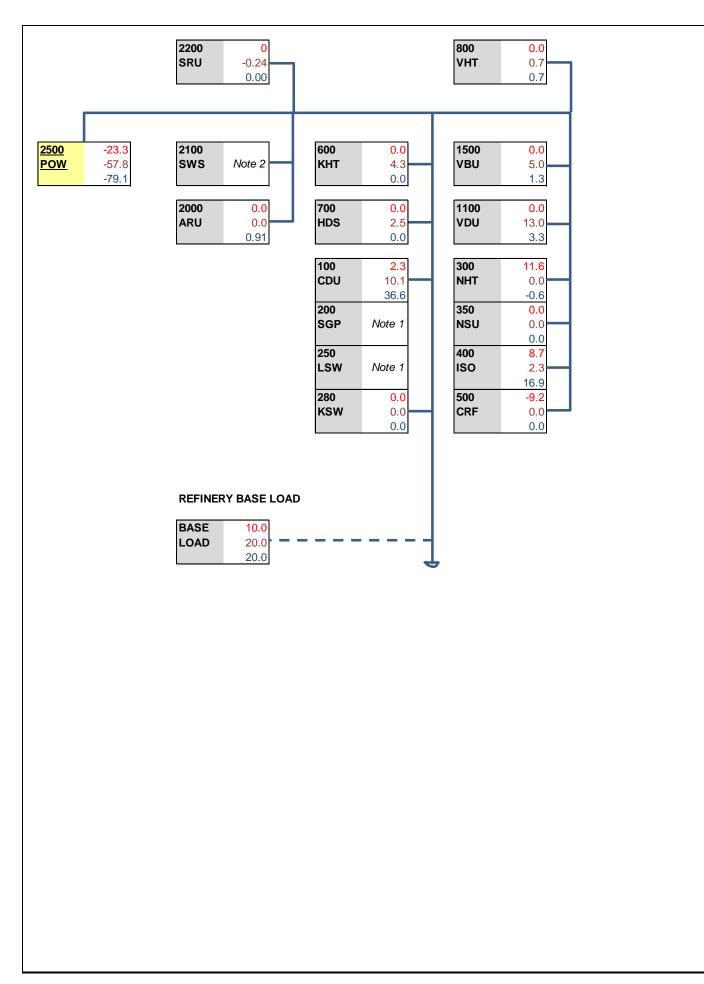


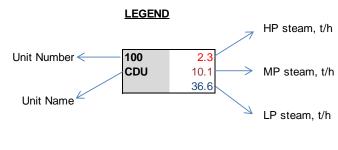
Figure 5-3: Base Case 1) Electricity network

COMMENTS	CG	CG	MCS
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- ELECTRICITY		NORK	
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Positive figures: consumptions

Negative figures: productions





NOTES

1) Include 2) Include

_ HP steam, t/h □			
Hr steam, th			
2.3			
10.1 MP steam, t/h Positive figures:			
36.6 Negative figures:	producti	ons	
LP steam, t/h			
I in 100-CDU consumptions I in Base Load			
F01 12/05/16 INCLUDING COMMENTS	CG	CG	MCS
C00 30/10/15 FIRST ISSUE	LB	CG	MCS
C00 30/10/15 FIRST ISSUE			
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Figure 5-4: Base Case 1) Steam networks

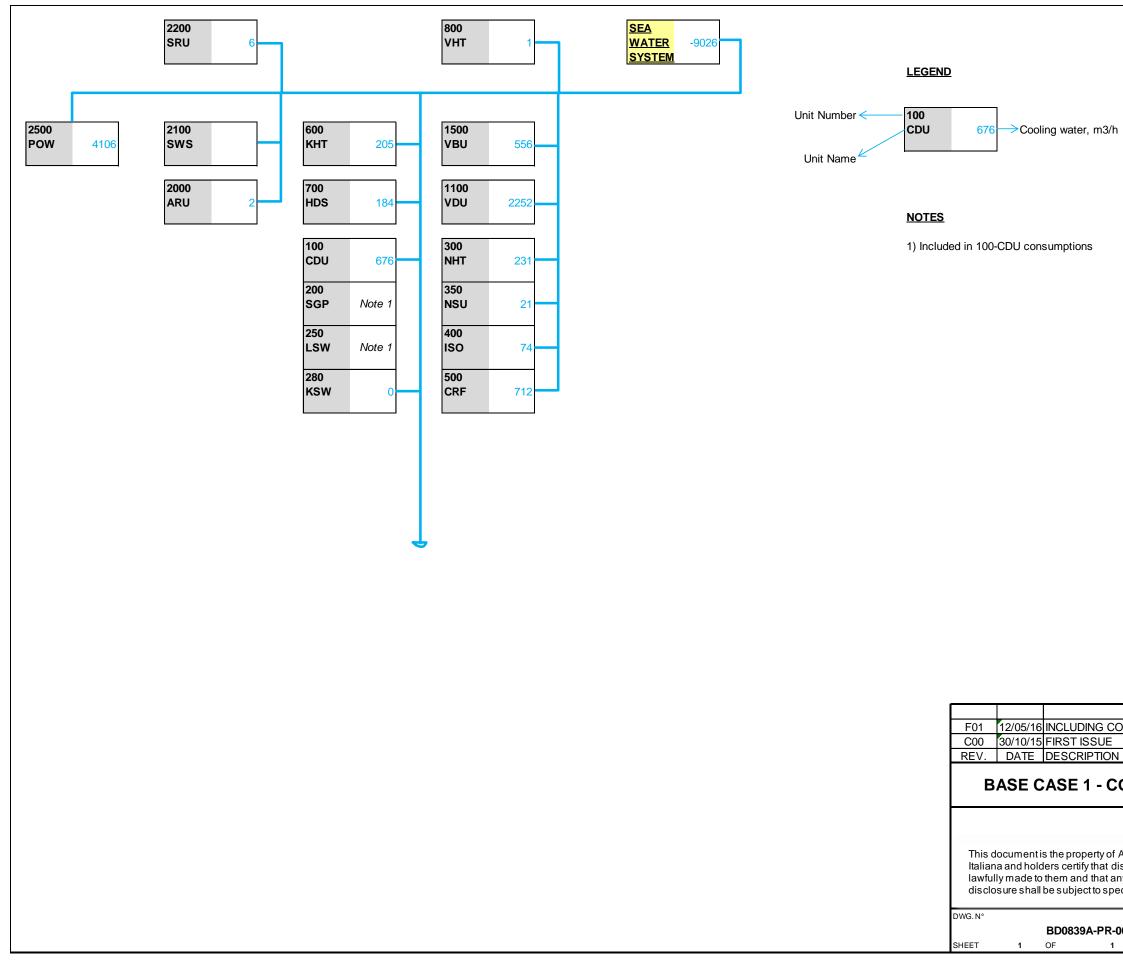
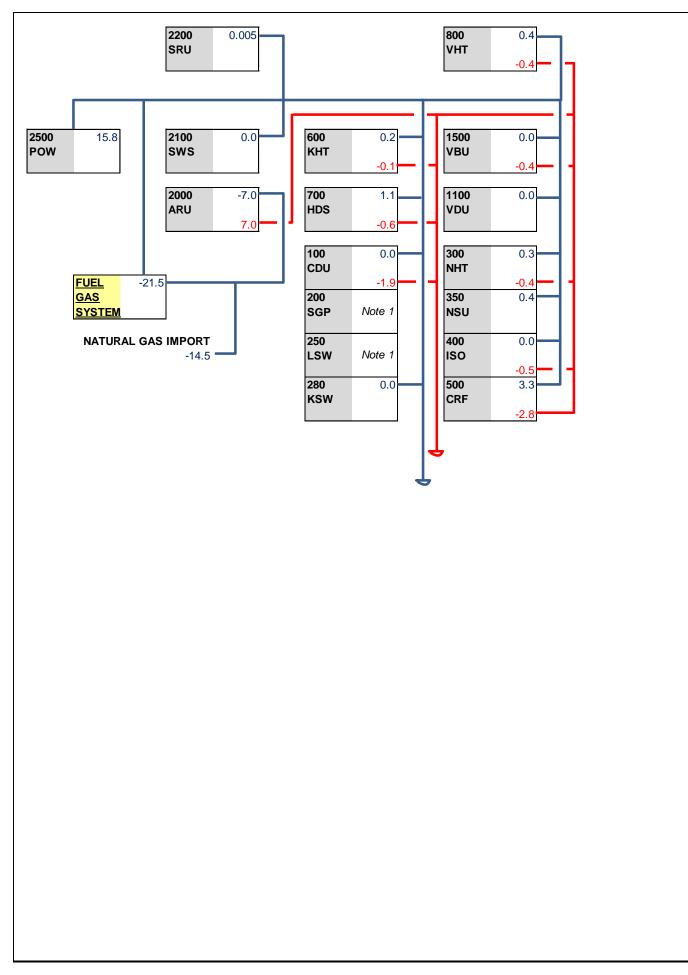
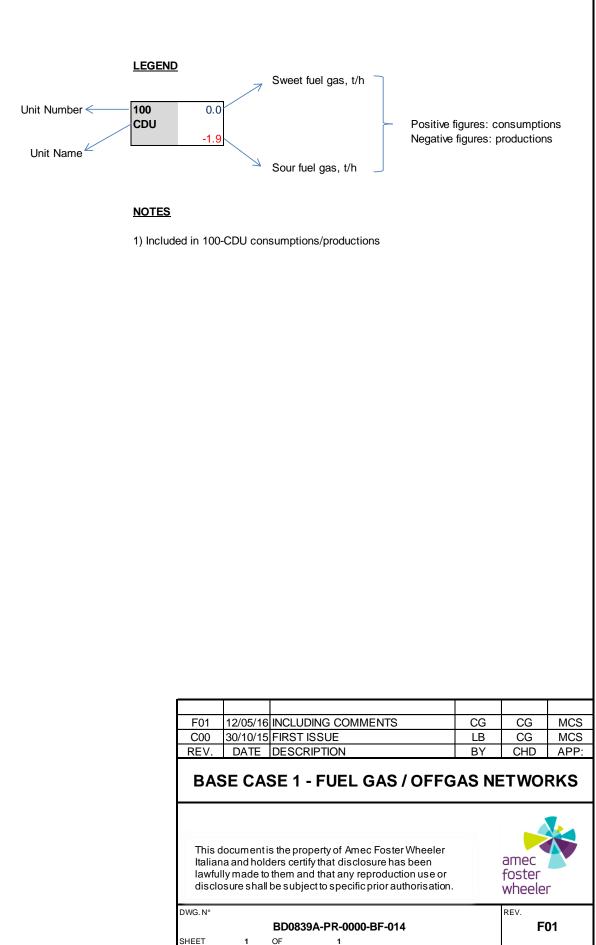


Figure 5-5: Base Case 1) Cooling water network

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h Positive figu Negative figu	res: cons ures: prod	umptions luctions			
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Figure 5-6: Base Case 1) Fuel Gas/Offgas networks

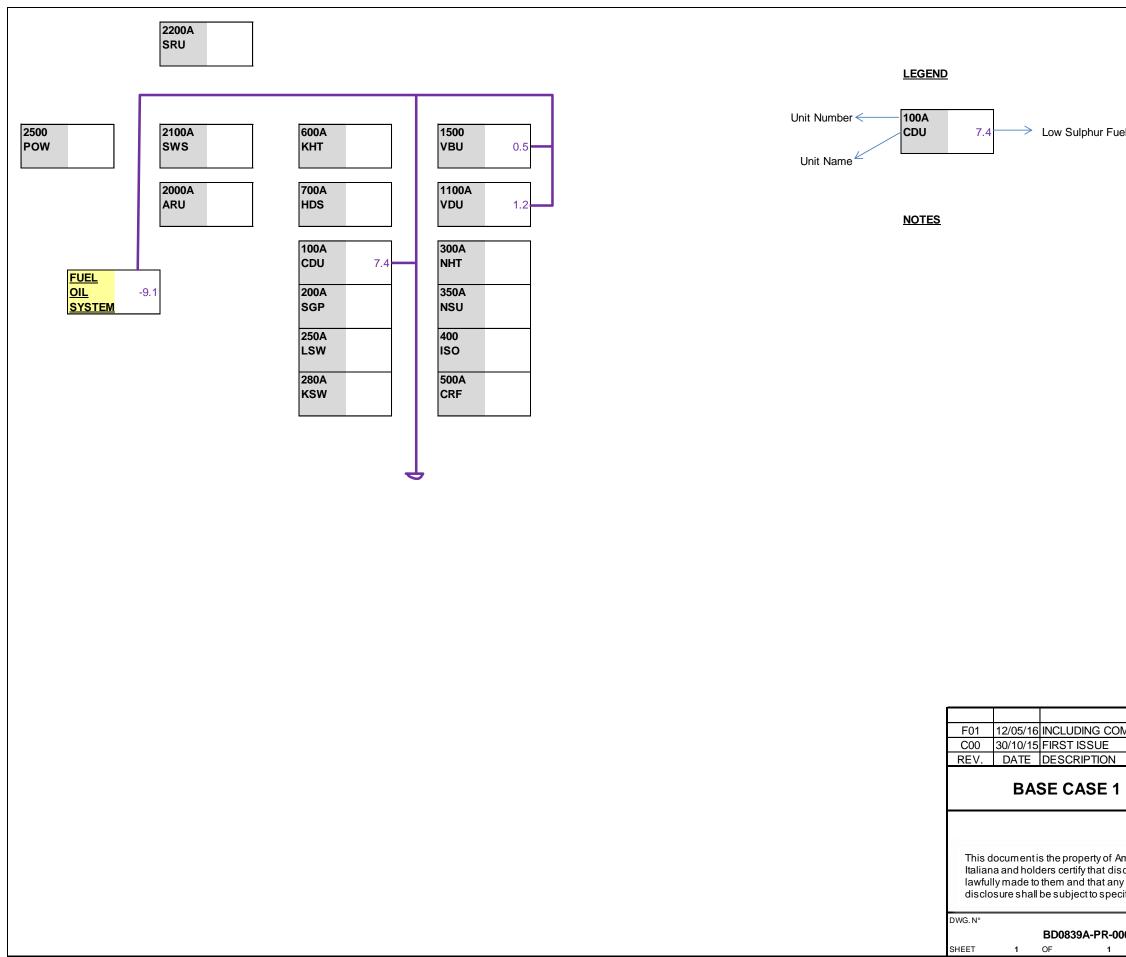


Figure 5-7: Base Case 1) Fuel oil network

		consump production	
COMMENTS	CG	CG	MCS
E DN	LB BY	CG CHD	MCS APP:
1 - FUEL OIL N			
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5.4 Configuration of Power Plant

A dedicated study has been carried out to define the most suitable power plant configuration to satisfy the power/steam demand from the refinery for Base Case 1.

A key aspect for the development of the study and for the definition of the power plant configuration has been the age of the refinery: for the design it has been considered the best available technologies at the time of construction of the refinery and the calculated power plant performances take into account the obsolescence of the machines.

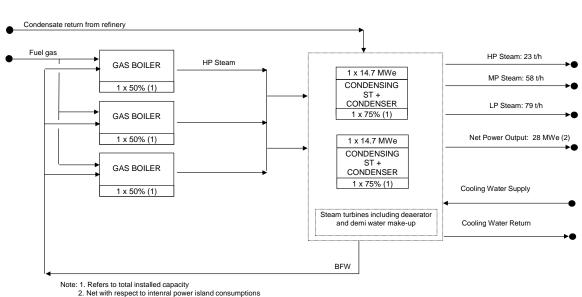
For Base Case 1, the power and steam demand are summarized in the main utility balance in Table 5-6.

The power plant has been designed to be normally operated synchronized and in balance with the grid and with the refinery and such that no import/export of steam is required during normal operation. However, steam demand has higher priority over electricity demand, since refinery electrical demand can be provided by HV grid connection back-up.

Power Plant configuration for Base Case 1 is a steam cycle. High pressure steam is generated at the pressure level required by the refinery in a conventional gas boiler: HP steam generated is partially routed to the refinery, to satisfy the HP steam demand, and partially sent to extracting steam turbines for power and MP/LP steam generation. MP and LP steam are generated through two different extraction stages at the pressure required by the users. Steam turbines are condensing type: exhaust steam from the steam turbine is condensed into a condenser, which operates under vacuum, and pumped, together with a demiwater make up, to deaerator for BFW generation.

It is assumed that 50% of steam exported to refinery returns as atmospheric condensate while the rest is made up with demineralised water.

Power plant configuration proposed for Base Case 1 is summarized in the following sketch.



BASE CASE 1

Figure 5-8: Base Case 1) Power Plant simplified Block Flow Diagram



Major equipment number and sizes are summarized hereinafter:

- > 3 x 115 t/h Gas Boilers, normally operated at 69% of their design load (corresponding to 79.3 t/h each)
- 2 x 20 MWe Condensing Steam Turbines, normally operated at 74% of their design load (corresponding to 14.7 MWe each)

The system has been conceived to have such an installed spare capacity both for power and steam generation to handle possible oscillations in power/steam demand from refinery users and to avoid refinery shutdown in case one equipment (boiler or turbine) trips.

In case one of the steam turbines trips, however, only 68% of the total power demand is guaranteed: in this scenario, a load shedding is necessary unless there is the possibility to import the remaining electrical demand from the HV grid.

Total installed spare capacity is summarized hereinafter:

- Gas Boilers (Steam) +45%
- Steam Turbines (Electric Energy) +37%



6. Base Case 2

Medium Conversion Refinery - 220,000 BPSD Crude Capacity

The Medium Conversion Refinery, with respect of the Hydro-skimming Refinery described at paragraph 5, includes additional process units for the conversion of the Vacuum Gasoil (VGO) into more valuable distillates (essentially gasoline and automotive diesel).

In Europe, the most wide-spread VGO conversion unit is the Fluid Catalytic Cracking (FCC) and so this unit is included in Base Case 2.

Upstream of the FCC, a Vacuum Gasoil Hydrotreating (VHT) unit is present to decrease the sulphur content of FCC feedstock, in order to respect SO_x limits at FCC stack.

The hydrogen from the Heavy Naphtha Catalytic Reformer is not enough to cover the overall hydrogen demand of the refinery. Therefore, a Steam Methane Reformer (SMR) is also foreseen to close the hydrogen balance.

The FCC products are sent to finishing units to comply with the 10 ppm wt. sulphur specification for the automotive fuels.

The overall configuration of Base Case 2 is considered as a step-up evolution of Base Case 1, both in terms of capacity and complexity increase. In other words, it is considered that, in a simple hydro-skimming refinery (as the one depicted as Base Case 1), a second crude distillation train (Atmospheric and Vacuum Distillation Units) and FCC block (VHT+FCC+SMR) are built in a second phase. The consequent capacity increase of the gasoline block and the hydrotreating units is considered achieved by adding a second train in parallel to the original one.

The above assumption reflects the typical "life" of the European refineries, which have gradually expanded starting from an original nucleus. This results in the following main effects:

- Several units of the same type are running in parallel, resulting in a relatively good flexibility of the processing scheme (e.g. different feedstocks could be fed to each train) but also, on the other hand, in some inefficiencies (e.g. higher maintenance costs, lower energy efficiencies, etc.).
- Also the Power Plant in Base Case 2 is considered as an expansion of the facilities foreseen in Base Case 1, reflecting the "modular" expansion of the original refinery into a bigger, more complex and more demanding site.
- The increased demand of cooling water –with respect of cooling water consumption in Base Case 1- is considered to be satisfied by a closed loop circuit with cooling towers, working in parallel to the original open circuit of sea cooling water. As a matter of fact, for the upgrading of the refinery, it is assumed that more stringent environmental regulations have been met.
- Finally, also the layout of the Base Case 2 refinery reflects two main areas of units' allocation: beside the original nucleus of the older units (unit numbers identified with suffix –A), a second block of units is present and clearly identifiable (unit numbers identified with suffix –B). The FCC block is included in this newer portion of the refinery.

6.1 Refinery Balances

The balances developed for Base Case 2 are reported in the following tables and figures:

- Table 6-1: Base Case 2) Overall material balance
- Table 6-2: Base Case 2) Process units operating and design capacity



- ▶ Table 6-3: Base Case 2) Gasoline qualities
- ▶ Table 6-4: Base Case 2) Distillate qualities
- ▶ Table 6-5: Base Case 2) Fuel oil and bitumen qualities
- ▶ Table 6-6: Base Case 2) Main utility balance, fuel mix composition, CO₂ emissions
- Figure 6-1: Base Case 2) Block flow diagrams with main material streams
- ▶ Table 6-7: Base Case 2) CO2 emissions per unit

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ReCAP Project Preliminary Refinery Balances



BASE CASE 2 Medium Conversion Refinery, 220,000 BPSD

OVERALL MATERIAL BALANCE

PRODUCTS	Annual Production, kt/y
LPG	559.8
Propylene	164.3
Petrochemical Naphtha	108.4
Gasoline U95 Europe	1753.1
Gasoline U92 USA Export	751.3
Jet fuel	1000.0
Road Diesel	3411.8
Marine Diesel	87.2
Heating Oil	1050.1
Low Sulphur Fuel Oil	149.1
Medium Sulphur Fuel Oil	405.6
High Sulphur Fuel Oil	933.7
Bitumen	260.0
Sulphur	49.2
Subtotal	10683.5
RAWMATERIALS	Consumptions, kt/y
Ekofisk	2515.6
Bonny Light	3050.0
Arabian Light	1015.0
Urals Medium	3050.0
Arabian Heavy	305.0
Maya Blend (1)	489.4
Imported Vacuum Gasoil	476.6
MTBE	0.0
Natural Gas	240.2
Biodiesel	213.4
Ethanol	92.3
Subtotal	11447.6
	kt/y
Fuels and Losses	764.1

Notes

1) Maya Blend consists of 50% wt. Maya crude oil + 50% wt. Arabian Light Crude Oil

REV.8 12/05/2016

ReCAP Project Preliminary Refinery Balances



BASE CASE 2 Medium Conversion Refinery, 220,000 BPSD

PROCESS UNITS OPERATING AND DESIGN CAPACITY

UNIT	Unit of measure	Design Capacity	Operating Capacity	Average Utilization
Crude Distillation Unit	BPSD	220000 (1)	220000 (1)	100%
Vacuum Distillation Unit	BPSD	80000 (1)	72034 (1)	90%
Naphtha Hydrotreater	BPSD	50000 (1)	46195	92%
Light Naphtha Isomerization	BPSD	15000	13988	93%
Heavy Naphtha Catalytic Reforming	BPSD	33000 (1)	30301	92%
Kero Sweetening	BPSD	15000 (1)	15000	100%
Kerosene Hydrotreater	BPSD	19000 (1)	18174	96%
Diesel Hydrotreater	BPSD	60000 (1)	60000	100%
Heavy Gasoil Hydrotreater	BPSD	35000	33308	95%
Fluid Catalytic Cracking	BPSD	50000	50000	100%
FCC Gasoline Hydrotreater	BPSD	20000	19273	96%
Visbreaking	BPSD	28000	26228	94%
Sulphur Recovery Unit	t/d Sulphur	220 (1)	141	64%
Steam Reformer	Nm ³ /h Hydrogen	22500	19724	88%

Notes

1) Multiple units in parallel to be considered.

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EXCESS NAPH	THA		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
NAH	HT HEAVY NAPHTHA		8,782.63	8.103%	11,772.96	7.611%
NAL	HT LIGHT NAPHTHA		64,337.19	59.358%	92,305.86	59.676%
LCN	FCC LIGHT NAPHTHA	treated	1,963.13	1.811%	2,745.64	1.775%
NSCR5	STAB NAPHTHA ARA	B.HEAVY	33,306.00	30.728%	47,853.45	30.937%
		Total	108,388.95	100.000%	154,677.91	100.000%
Quality			Blending Basis	Value	Min	Max
			VL	700.74		725.00
RHO	DENSITY, KG/M3		VL			
RHO SPM VPR	UENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE,	КРА	VL WT VL	62.24 69.00		500.00 69.00
SPM	SULFUR, PPMW VAPOR PRESSURE,	KPA	WT	62.24	Volume	500.00
SPM VPR	SULFUR, PPMW VAPOR PRESSURE,	КРА	WT	62.24 69.00	Volume Quantity	500.00
SPM VPR Unl. Premium Component BU#	SULFUR, PPMW VAPOR PRESSURE,	KPA	WT VL	62.24 69.00		500.00 69.00
SPM VPR Unl. Premium Component BU# R10	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100	KPA	WT VL Weight Quantity 12,656.60 785,262.42	62.24 69.00 Weight Percent	Quantity	500.00 69.00 Volume Percent
SPM VPR Unl. Premium Component BU# R10 ISO	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE		WT VL Weight Quantity 12,656.60 785,262.42 275,236.94	62.24 69.00 Weight Percent 0.722% 44.794% 15.700%	Quantity 21,700.02 947,240.55 416,394.76	500.00 69.00 Volume Percent 0.934% 40.772% 17.923%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA		WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371%
SPM VPR Unl. Premium Component BU# R10 ISO	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE	, treated	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA		WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA	, treated	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA	, treated	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL	, treated	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000%	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE,	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00 1.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN ARO	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, BENZENE, %V	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00 0.71	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00 1.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN ARO E50	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, BENZENE, %V AROMATICS, %V	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL VL VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00 0.71 32.01	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min 720.00	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN ARO E50 OXY	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, BENZENE, %V AROMATICS, %V D86 @ 150°C, %V	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL VL VL VL VL VL VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00 0.71 32.01 91.03	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min 720.00	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00 15.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN ARO E50 OXY OLE EOH	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL VL VL VL VL VL VL VL VL VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00 0.71 32.01 91.03 5.00	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min 720.00	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 60.00 1.00 60.00 1.00 15.00 18.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality	SULFUR, PPMW VAPOR PRESSURE, (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	treated Total	WT VL Weight Quantity 12,656.60 785,262.42 275,236.94 587,550.95 92,349.08 1,753,055.99 Blending Basis VL WT VL VL VL VL VL VL VL	62.24 69.00 Weight Percent 0.722% 44.794% 15.700% 33.516% 5.268% 100.000% Value 754.57 3.39 60.00 0.71 32.01 91.03 5.00 14.53	Quantity 21,700.02 947,240.55 416,394.76 821,749.57 116,162.36 2,323,247.27 Min 720.00	500.00 69.00 Volume Percent 0.934% 40.772% 17.923% 35.371% 5.000% 100.000% Max 775.00

REV 12/05/ Unl. Premium (2016 Preli Medium Col <u>G</u>	ReCAP Project minary Refinery B BASE CASE 2 oversion Refinery ASOLINE QUALI	alances , 220,000 BPSD	fo	nec oster heeler
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
BU#	C4 TO MOGAS/LPG	6,180.30	0.823%	10,596.27	1.043%
R10	REFORMATE 100	338,954.93	45.115%	408,872.05	40.264%
ISO	ISOMERATE	244,508.13	32.544%	369,906.40	36.427%
LCN	FCC LIGHT NAPHTHA treated	161,666.35	21.518%	226,106.78	22.266%
	Tot	al 751,309.71	100.000%	1,015,481.49	100.000%
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	739.86	720.00	775.00
SPM	SULFUR, PPMW	WT	2.19		10.00
VPR	VAPOR PRESSURE, KPA	VL	60.00		60.00
BEN	BENZENE, %V	VL	0.68		1.00
ARO	AROMATICS, %V	VL	29.72		35.00
E50	D86 @ 150°C, %V	VL	91.14	75.00	
OXY	OXYGENATES, %V	VL	0.00		15.00
OLE	OLEFINS, %V	VL	9.39		18.00
EOH	ETHANOL, VOI%	VL	0.00		10.00
RON	Research	VL	92.00	92.00	
MON	Motor	VL	84.00	84.00	

		ReCAP Project inary Refinery B BASE CASE 2 ersion Refinery	alances	f	amec oster vheeler
LPG PRODUCT		TILLATE QUAL	ITIES		
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
LG#	LPG POOL	559,790.66	100.000%	984,736.23	100.000%
	Total	559,790.66	100.000%	984,736.23	100.000%
Quality		Blending Basis	Value	Min	Max
SPM	SULFUR, PPMW	WT	5.00		140.00
VPR	VAPOR PRESSURE, KPA	VL	622.89		887.6
OLW	OLEFINS, %W	WT	0.78		30.00
Component		Weight Quantity		Volume Quantity	Volume Percen
KED		332,718.22	33.272%	419,304.62	33.438%
KMCR3 KMCR4	KERO FROM MEROX AR.LIGHT	108,750.20 458,415.00	10.875%	135,598.75 573,735.92	10.8139
KMCR4 KMCR5	KERO FROM MEROX URALS KERO FROM MEROX AR.HVY	458,415.00 36,295.00		45,368.75	45.753% 3.618%
KMCR6	KERO FROM MEROX MAYA	63,821.58		79,976.92	6.378%
	Total		100.000%	1,253,984.97	100.000%
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	797.46	775.00	840.0
SUL	SULFUR, %W	WT	0.12		0.3
FLC Diesel EU	FLASH POINT, °C (PM, D93)	VL	40.00	38.00	
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percen
LCO	LIGHT CYCLE OIL treated	193,322.80	5.666%	203,497.69	5.035%
HCN	FCC HEAVY NAPHTHA	375,590.21	11.009%	441,870.84	10.933%
KED	HT KERO	469,302.16		591,433.10	14.633%
DLG	DESULF LGO	2,160,135.16	63.314%	2,562,437.92	63.399%
FAM	BIODIESEL	213,404.09		242,504.65	6.000
	Total	3,411,754.44	100.000%	4,041,744.19	100.000%
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	844.13	820.00	845.0
SPM	SULFUR, PPMW	WT	9.10		10.0
FLC	FLASH POINT, °C (PM, D93)	VL	55.00	55.00	
CIN	CETANE INDEX D4737	VL	48.16	46.00	
V04	VISCOSITY @ 40°C, CST	WT VL	2.45	2.00 95.00	4.5
		NI VI	97.53	<u>us nn</u>	
E36 FAM	D86 @360°C, %V BIODIESEL CONTENT, %VOL	VL	6.00	6.00	7.0

	5/2016	Medium Conv	ReCAP Project nary Refinery B BASE CASE 2 ersion Refinery	alances , 220,000 BPSD	amec foster wheeler		
Heating Oil							
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent	
KSCR1			323,482.12	30.806%	403,847.84	32.904%	
LGCR2			381,343.03	36.316%	437,822.08	35.672%	
H1CR2	HGO BON	INY	121,726.52	11.592%	133,721.33	10.895%	
VLG	DESULF I	_GO ex VHT	50,926.81	4.850%	60,268.41	4.910%	
LVCR2	LVGO BO	NNY	172,589.65	16.436%	191,702.38	15.619%	
		Total	1,050,068.13	100.000%	1,227,362.03	100.000%	
Quality		Blending Basis	Value	Min	Max		
RHO	HO DENSITY, KG/M3		VL	855.55	815.00	860.00	
SPM	SULFUR,		WT	1,000.00		1,000.00	
FLC		DINT, °C (PM, D93)	VL	55.00	55.00		
CIN		NDEX D4737	VL	46.72	40.00		
V04		Y @ 40°C, CST	WT	3.09	2.00	6.00	
MARINE DIESE	iL		Weight Quantity	Weight Percent	Volume	Volume Percent	
		FKOFICK		-	Quantity	00.000	
KSCR1 LGCR2			18,873.59	21.648% 2.455%	23,562.53		
LGCR2 H1CR2	LGO BON HGO BON		2,140.36 39,313.48		<u>2,457.35</u> 43,187.39		
VLG		_GO ex VHT	26,855.93	30.804%	43,187.39		
VLG		Total	87,183.35	100.000%	100,989.44		
Quality			Blending Basis	Value	Min	Max	
RHO	DENSITY,	KG/M3	VL	863.29		890.00	
	SULFUR,		WT	1,000.00		1,000.0	
			VL	60.00	60.00		
SPM	FLASH PO	DINT, °C (PM, D93)	V L				
SPM FLC CIN		DINT, °C (PM, D93) NDEX D4737	VL	46.99	35.00		

	V.8 5/2016	Medium Conv	ReCAP Project nary Refinery Ba BASE CASE 2 ersion Refinery, L / BITUMEN QI	alances 220,000 BPSD	f	oster vheeler
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
SLU	FCC SLU	RRY OII	25,340.95	7.986%	24,366.30	7.610%
lco		CLE OIL untreated	22,066.39	6.954%	23,227.78	7.255%
LCO		CLE OIL treated	15,040.81	4.740%	15.832.43	4.945%
VRCR1	VBRES M		50,540.30	15.928%	52,756.05	16.477%
VRCR2	VBRES M		171.018.58	53.898%	164,599.21	51.408%
VLG		LGO ex VHT	33,292.38	10.492%	39,399.26	12.305%
-	1	Total	317,299.41	100.000%	320,181.04	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY	, KG/M3	VL	991.00		991.00
SUL	SULFUR,		WT	0.50		0.50
FLC		OINT, °C (PM, D93)	VL	129.30	66.00	
V05		TY @ 50°C, CST	WT	380.00		380.00
				11.36		15.00
CCR		SON CARBON RES, %W	WT	11.30		
	CONRAD	SON CARBON RES, %W	Weight Quantity		Volume	Volume Percent
CCR Medium Sulph Component	CONRAD		Weight Quantity	Weight Percent	Quantity	Volume Percent
CCR Medium Sulph Component SLU	CONRAD	RRY OIL	Weight Quantity 167,462.02	Weight Percent 41.287%	Quantity 161,021.18	Volume Percent 39.501%
CCR Medium Sulph Component SLU Ico	CONRAD	RRY OIL CLE OIL untreated	Weight Quantity 167,462.02 27,663.62	Weight Percent 41.287% 6.820%	Quantity 161,021.18 29,119.60	Volume Percent 39.501% 7.143%
CCR Medium Sulph Component SLU Ico VRCR1	CONRAD	RRY OIL CLE OIL untreated	Weight Quantity 167,462.02 27,663.62 176,752.37	Weight Percent 41.287% 6.820% 43.578%	Quantity 161,021.18 29,119.60 184,501.43	Volume Percent 39.501% 7.143% 45.261%
CCR Medium Sulph Component SLU Ico	CONRAD	RRY OIL CLE OIL untreated	Weight Quantity 167,462.02 27,663.62	Weight Percent 41.287% 6.820%	Quantity 161,021.18 29,119.60	Volume Percent 39.501% 7.143%
CCR Medium Sulph Component SLU Ico VRCR1	CONRAD	RRY OIL CLE OIL untreated IIX1 IIX4	Weight Quantity 167,462.02 27,663.62 176,752.37 33,725.32	Weight Percent 41.287% 6.820% 43.578% 8.315%	Quantity 161,021.18 29,119.60 184,501.43 32,999.33	Volume Percent 39.501% 7.143% 45.261% 8.095%
CCR Medium Sulph Component SLU Ico VRCR1 VRCR4	CONRAD	RRY OIL CLE OIL untreated IIX1 IIX4 Total	Weight Quantity 167,462.02 27,663.62 176,752.37 33,725.32 405,603.33	Weight Percent 41.287% 6.820% 43.578% 8.315% 100.000%	Quantity 161,021.18 29,119.60 184,501.43 32,999.33 407,641.54	Volume Percent 39.501% 7.143% 45.261% 8.095% 100.000%
CCR Medium Sulph Component SLU Ico VRCR1 VRCR4 Quality	CONRAD	RRY OIL CLE OIL untreated IIX1 IIX4 Total	Weight Quantity 167,462.02 27,663.62 176,752.37 33,725.32 405,603.33 Blending Basis	Weight Percent 41.287% 6.820% 43.578% 8.315% 100.000% Value	Quantity 161,021.18 29,119.60 184,501.43 32,999.33 407,641.54	Volume Percent 39.501% 7.143% 45.261% 8.095% 100.000% Max
CCR Medium Sulph Component SLU Ico VRCR1 VRCR4 Quality RHO	CONRAD UT FUEI FCC SLU LIGHT CY VBRES M VBRES M DENSITY SULFUR,	RRY OIL CLE OIL untreated IIX1 IIX4 Total	Weight Quantity 167,462.02 27,663.62 176,752.37 33,725.32 405,603.33 Blending Basis VL	Weight Percent 41.287% 6.820% 43.578% 8.315% 100.000% Value 995.00	Quantity 161,021.18 29,119.60 184,501.43 32,999.33 407,641.54	Volume Percent 39.501% 7.143% 45.261% 8.095% 100.000% Max 995.00
CCR Medium Sulph Component SLU Ico VRCR1 VRCR4 VRCR4 RHO SUL	CONRAD UT FUEI FCC SLU LIGHT CY VBRES M VBRES M VBRES M UBRES M SULFUR, FLASH P	RRY OIL CLE OIL untreated IIX1 IIX4 Total KG/M3 %W	Weight Quantity 167,462.02 27,663.62 176,752.37 33,725.32 405,603.33 Blending Basis VL WT	Weight Percent 41.287% 6.820% 43.578% 8.315% 100.000% Value 995.00 1.00	Quantity 161,021.18 29,119.60 184,501.43 32,999.33 407,641.54 Min	Volume Percent 39.501% 7.143% 45.261% 8.095% 100.000% Max 995.00

I

12/0	5/2016	Medium Conv	ReCAP Project inary Refinery B BASE CASE 2 ersion Refinery L / BITUMEN Q	alances 220,000 BPSD	f	amec oster vheeler
High Sulphur Component	Fuel		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
lco	LIGHT CY	CLE OIL untreated	235,523.42	25.225%	247,919.39	26.314%
V1CR3	VBLGO N	IIX3	35,638.28	3.817%	41,927.39	4.450%
VRCR3	VBRES N	IIX3	165,318.53	17.706%	165,815.98	17.599%
VRCR4	VBRES M	IIX4	497,204.99	53.252%	486,501.95	51.637%
		Total	933,685.21	100.000%	942,164.70	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY,	KG/M3	VL	991.00		991.00
SUL	SULFUR,	%W	WT	3.00	1.00	3.50
FLC	FLASH P	DINT, °C (PM, D93)	VL	124.35	60.00	
V05	VISCOSIT	Y @ 50°C, CST	WT	380.00		380.00
CCR	CONRAD	SON CARBON RES, %W	WT	14.58		18.00
BITUMEN						
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
VDCR5	VDU RES	MIX5	107,884.28	41.494%	106,289.93	41.921%
VDCR6	VDU RES	MIX6	152,115.72	58.506%	147,256.26	58.079%
		Total	260,000.00	100.000%	253,546.19	100.000%

REV.8 12/05/2016	amec foster wheeler						
		MAIN U	TILITY BALA	NCE			
	FUEL	POWER	HP STEAM	MP STEAM		COOLING WATER (2)	RAW WATER
	Gcal/h	kW	tons/h	tons/h	tons/h	m3/h	m3/h
MAIN PROCESS UNITS	485	32148	34	121	129	25122	
BASE LOAD	400	22500	15 -49	30	30	0560	
POWER PLANT SEA WATER SYSTEM	400	-60415 1712	-49	-151	-159	8563 -10000	
COOLING TOWER SYSTEM		4055				-10000	
		+000				-2000	
TOTAL	885	0	0	0	0	0	2590
LOW SULPHUR FUEL OIL (3) FCC COKE NATURAL GAS	20.0 12.1 22.7	168.2 101.4 190.5	25% 15% 28%				
TOTAL	81.4	684.1					
		<u>C02</u>	EMISSIONS	<u>5</u>			
	t/h						
From Steam Reformer	15.7						
From FG/NG combustion	133.4						
From FO combustion	64.1						
From FCC coke combustion	44.3						
TOTAL				2162.3 207.4	kt/y kg CO2 / t cr	ude	
Notes 1) (-) indicates productions 2) 10°C temperature increase h 3) LSFO is burnt in CDU, VDU			_				

REV.8 12/05/2016

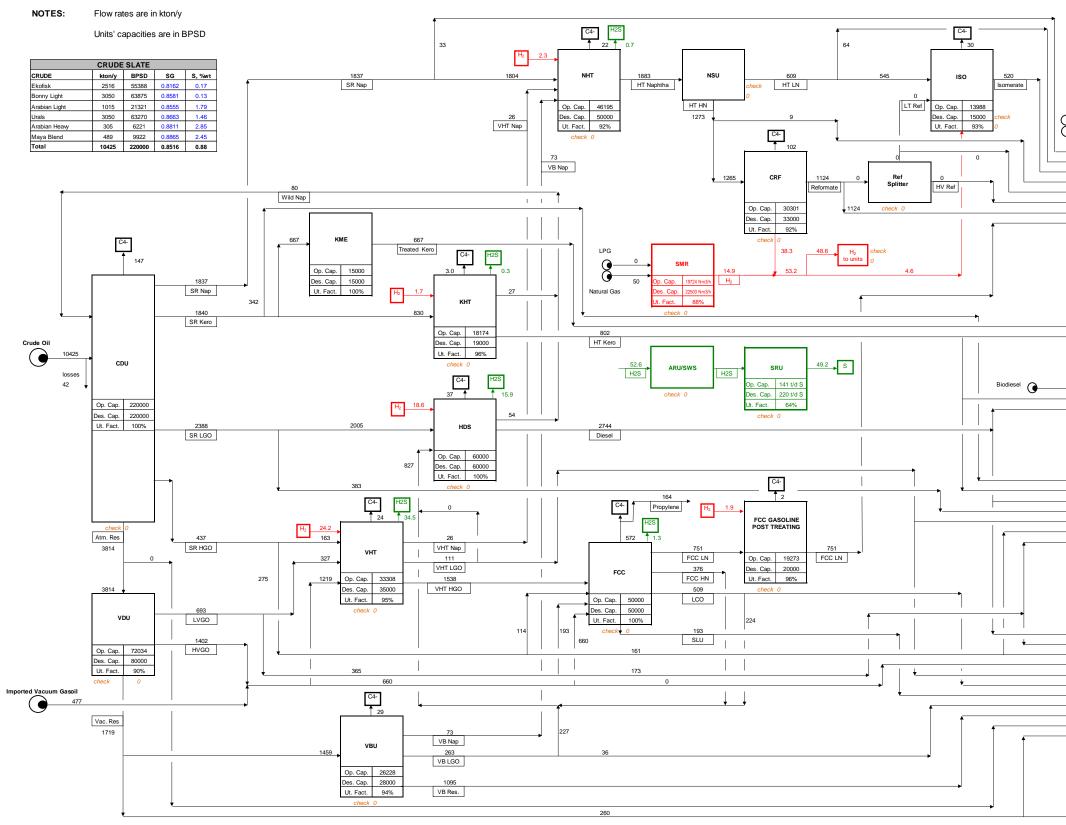
ReCAP Project

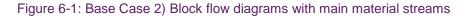
Overall Refinery Balance

BASE CASE 2

Medium Conversion Refinery, 220,000 BPSD

BLOCK FLOW DIAGRAM





	LPG
Propane	94
Butane	465
Total prod.	560
To SMR	0
To fuel	0
Sales	560

	Propylene
Propylene	164
Sales	164

		U 95-EU	U 92-US	Excess Naph.	тот
` .	MTBE	0	0	0	0
3	Ethanol	92	0	0	92
_ _	Butanes	13	6	0	19
	SR Naphtha	0	0	33	33
	HT Light Naphtha	0	0	64	64
	Isomerate	275	245	0	520
	HT Heavy Naphtha	0	0	9	9
	LT Reformate	0	0	0	0
	HV Reformate	0	0	0	0
	Reformate	785	339	0	1124
	FCC LN	588	162	2	751
	Sales	1753	751	108	2613

	Jet Fuel
Treated Kero	667
HT Kero	333
Sales	1000
-	
	Diesel
Biodiesel	Diesel 213
Biodiesel HT Kero	
*	213
HT Kero	213 469

	Heating Oil	Mar. Dies.	тот
SR Kero	323	19	342
HT Kero	0	0	0
Diesel	0	0	0
SR LGO	381	2	383
VHT LGO	51	27	78
SR HGO	122	39	161
SR LVGO	173	0	173
Sales	1050	87	1137

	LSFO	MSFO	HSFO	тот
Diesel	15	0	0	15
SR LVGO	0	0	0	0
SR HGO	0	0	0	0
SR HVGO	0	0	0	0
VHT LGO	33	0	0	33
LCO untreated	22	28	236	285
SLU	25	167	0	193
VB LGO	0	0	36	36
VB Residue	222	210	663	1095
Atm. Residue	0	0	0	0
Vac. Residue	0	0	0	0
Total prod.	302	406	934	1642
To RFO	168	-	-	168
Sales	134	406	934	1473

		Bitumen		Sulphur
	/ac. Res.	260	Sulphur	49
s	Sales	260	Sales	49

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ReCAP Project 1-BD-0839A

CO₂ EMISSION PER UNIT - BASE CASE 2

					PROCES	SUNITS								
		UNIT		Desire Conseitu	Operatin	ig Fuel Consum	ption [t/h]	Operat	ing CO ₂ Emissi	on [t/h]	% on Total	·		Notes
	UNIT		Unit of measure	Design Capacity	Fuel Gas	Fuel Oil	Coke	Fuel Gas	Fuel Oil	Coke	CO ₂ Emission	n in flue gases, vol %	Temperature [°C]	(1)
0100A	CDU	Crude Distillation Unit	BPSD	100000	-	7.4	-	-	23.6	-	9.2%	11.3%	200 ÷ 220	
0100B	CDU	Crude Distillation Unit	BPSD	120000	-	8.9	-	-	28.3	-	11.0%	11.3%	200 ÷ 220	(2)
0300A	NHT	Naphtha Hydrotreater	BPSD	23000	0.3	-	-	0.9	-	-	0.3%	8.3%	420 ÷ 450	(2)
0350A	NSU	Naphtha Splitter Unit	BPSD	23000	0.4	-	-	1.1	-	-	0.4%	8.3%	420 - 450	(3)
0300B	NHT	Naphtha Hydrotreater	BPSD	27000	0.3	-	-	0.8	-	-	0.3%	8.3%	420 ÷ 450	(2)
0350B	NSU	Naphtha Splitter Unit	BPSD	27000	0.4	-	-	1.0	-	-	0.4%	8.3%	420 - 450	(3)
0500A	CRF	Catalytic Reforming	BPSD	15000	3.6	-	-	9.8	-	-	3.8%	8.3%	180 ÷ 190	
0500B	CRF	Catalytic Reforming	BPSD	18000	3.6	-	-	9.8	-	-	3.8%	8.3%	180 ÷ 190	T
0600A	KHT	Kero HDS	BPSD	14000	0.2	-	-	0.5	-	-	0.2%	8.3%	420 ÷ 450	
0600B	KHT	Kero HDS	BPSD	5000	0.1	-	-	0.3	-	-	0.1%	8.3%	420 ÷ 450	
0700A	HDS	Gasoil HDS	BPSD	26000	1.3	-	-	3.4	-	-	1.3%	8.3%	420 ÷ 450	
0700B	HDS	Gasoil HDS	BPSD	34000	1.4	-	-	3.9	-	-	1.5%	8.3%	420 ÷ 450	
0800	VHT	Vacuum Gasoil Hydrotreater	BPSD	35000	2.2	-	-	5.8	-	-	2.3%	8.3%	200 ÷ 220	
1000	FCC	Fluid Catalytic Cracking	BPSD	50000	-	-	12.1	-	-	44.3	17.2%	16.6%	300 ÷ 320	
1100A	VDU	Vacuum Distillation Unit	BPSD	35000	-	1.2	-	-	3.8	-	1.5%	11.3%	380 ÷ 400	
1100B	VDU	Vacuum Distillation Unit	BPSD	45000	-	1.5	-	-	4.9	-	1.9%	11.3%	200 ÷ 220	(2)
1200	SMR	Steam Reformer		22500	1.4	-	-	3.7	-	-	1.4%	8.3%	125 : 100	
1200	SIVIR	Steam Reformer Feed	Nm ³ /h Hydrogen	22500	5.9	-	-	15.7	-	-	6.1%	24.2%	135 ÷ 160	(4)
1500	VBU	Visbreaking Unit	BPSD	28000	-	1.0	-	-	3.4	-	1.3%	8.3%	380 ÷ 400	
						Sub Tota	I Process Units		164.9		64.1%			

	AUXILIARY UNITS													
2200A	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	55	0.005	-	-	0.01	-	-	0.0%	< 8%	380 ÷ 400	
2200B	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	2 x 82.5	0.014	-	-	0.04	-	-	0.0%	< 8%	380 ÷ 400	
						Sub Tota	al Auxiliary Units		0.05		0.0%			

	POWER UNITS													
2500	POW	Power Plant	kW	80000	34.2	-	-	92.5	-	-	35.9%	8.3%	130 ÷ 140	
	Sub Total Power Units 92.5							35.9%						
							=					-		
						TOTAL C	O ₂ EMISSION		257.5		100%			
								58%	25%	17%		-		

Notes

(1) Fuel gas is a mixture of refinery fuel gas (54%) and imported natural gas (46%).

(2) In train B, Crude and Vacuum Distillation heaters (units 0100B and 1100B) have a common stack.

(3) Both in train A and B, Naphtha Hydrotreater and Naphtha Splitter heaters (units 0300A/0350A and 0300B/0350B) have a common stack.

(4) Only natural gas is used as feed to the Steam Reformer, unit 1200; after reaction and hydrogen purification, tail gas and fuel gas are burnt in the Steam Reformer furnace.



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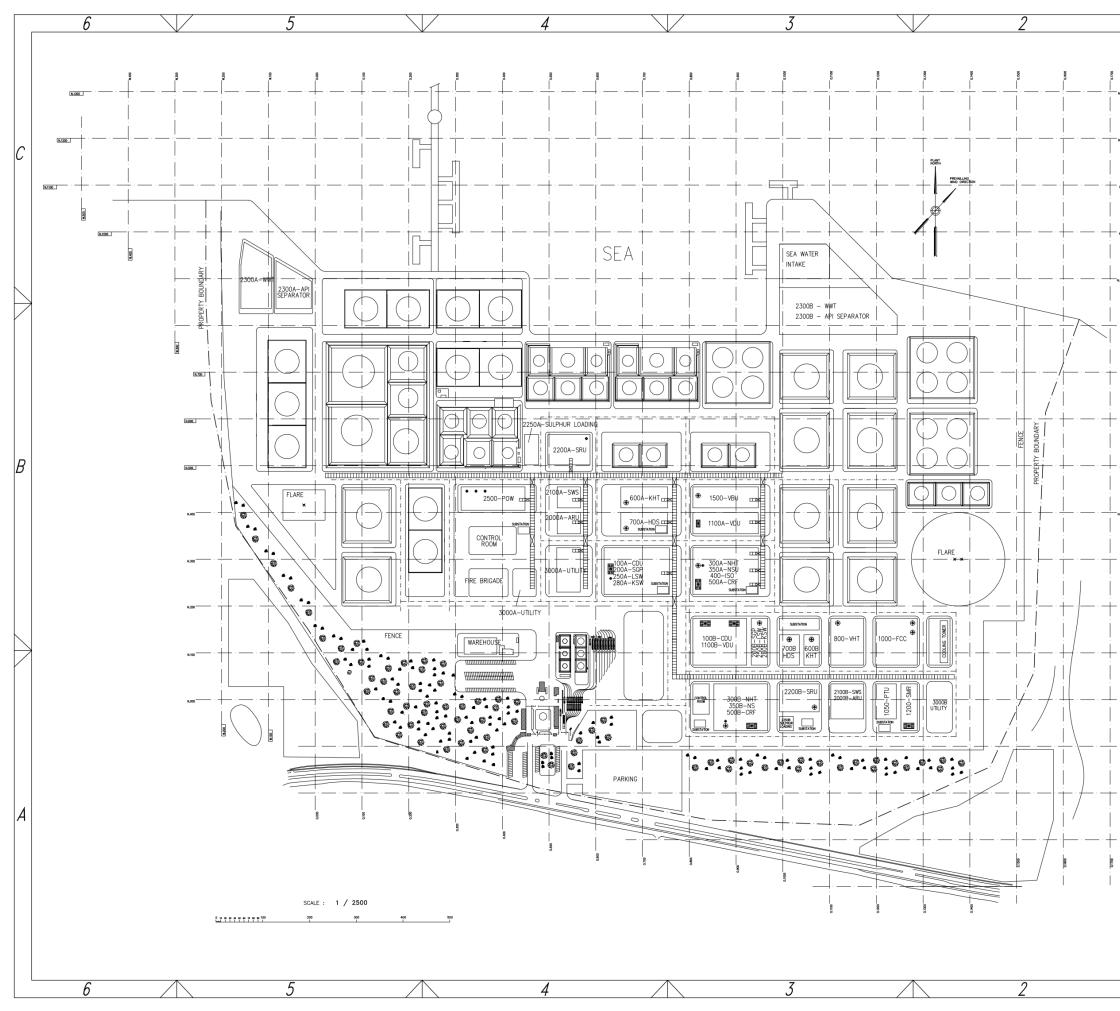


6.2 Refinery Layout

The layout of the medium conversion refinery has been developed starting from the plot plan of Base Case 1, essentially by adding a second block of process units beside the original nucleus of the refinery.

As already mentioned, this approach reflects the assumption of a refinery expanded, over its life, both in terms of capacity and complexity.

Also some auxiliary, utility and offsite systems, like for example the Waste Water Treatment (WWT) and the Flare, have been duplicated in the final configuration of the site.



			· · ·					
\backslash			1					
````	ſ		UNIT LIST					
	UN	IT	DESCRIPTION					
		100A	CRUDE DISTILLATION (CDU)					
1300		1100A	VACUUM DISTILLATION (VDU)					
		200A	SATURATED GAS PLANT (SGP)					
		250A	LPG SWEETENING (LSW)					
		200B	SATURATED GAS PLANT (SGP)					
.1200		250B	LPG SWEETENING (LSW)					
		280A	KERO SWEETENING (KSW)					$\mathcal{C}$
		280B	KERO SWEETENING (KSW)					Ŭ
s.1100		300A	NAPHTHA HYDROTREATER (NHT)					
		300B	NAPHTHA HYDROTREATER (NHT)					
	2	350A	NAPHTHA SPLITTER (NSU)					
1000	PROCESS UNITS	400	ISOMERIZATION (ISO)					
	DOES	350B	NAPHTHA SPLITTER (NSU)					
	PR	500A	CATALYTIC REFORMING (CRF)					
		500B	CATALYTIC REFORMING (CRF)					
100		$\vdash$						
		600A	KERO HDS (KHT))					
		600B	KERO HDS (KHT))					$ \leftarrow $
		700A	GASOIL HDS (HDS)					
N.800		700B	GASOIL HDS (HDS)					
		800	VACUUM GASOIL HYDROTREATER (VHT)					
		1000	FLUID CATALYTIC CRACKER (FCC)					
N.700		1050	FCC GASOLINE POST-TREATMENT UNIT (PTU)					
		100B	CRUDE DISTILLATION (CDU)					
		1100B	VACUUM DISTILLATION (VDU)					
N.600		1200	STEAM REFORMING (SMR)					
		1500	VISBREAKING UNIT (VBU)					
		2000A	AMINE WASHING AND REGENERATION (ARU)					
N.500		2000B	AMINE WASHING AND REGENERATION (ARU)					D
N.500		2100A	SOUR WATER STRIPPER (SWS)					D
		2100B	SOUR WATER STRIPPER (SWS)					
400		2200A	SULPHUR RECOVERY (SRU)					
			TAIL GAS TREATMENT					
	ST∎	2200B	SULPHUR RECOVERY (SRU)					
	۲ n	LUCOD	TAIL GAS TREATMENT					
	AUXILIARY UNITS	2250A	SULPHUR LOADING					
	AL	2250B	SULPHUR LOADING					
			WASTE WATER TREATMENT (WWT)					
		2300A						
			API SEPARATOR					
		2300B	WASTE WATER TREATMENT (WWT)					
			API SEPARATOR					
	12 E	2500	POWER PLANT (POW)					
	POWER							
		3000A	UTILITY UNITS					
		3000B	UTILITY UNITS					
	-	4000	OFF SITES UNITS					
		4000	or and units					
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# 6.3 Main Utility Networks

The main utility balances have been reported on block flow diagrams, reflecting the planimetric arrangement of the process units and utility blocks.

In particular, the following networks' sketches have been developed:

- Figure 6-3: Base Case 2) Electricity network
- Figure 6-4: Base Case 2) Steam networks
- Figure 6-5: Base Case 2) Cooling water network
- Figure 6-6: Base Case 2) Fuel Gas/Offgas networks
- Figure 6-7: Base Case 2) Fuel oil network

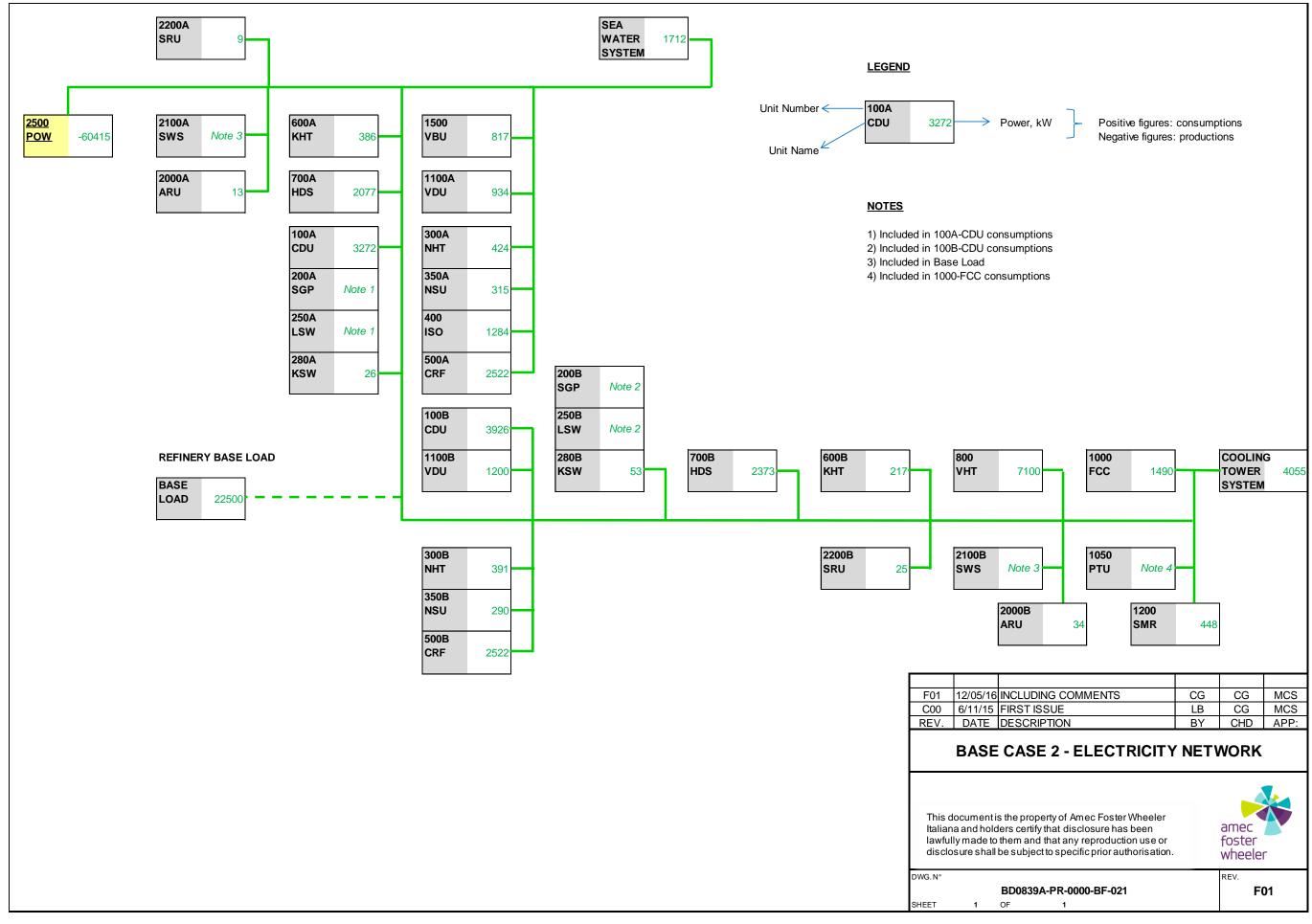


Figure 6-3: Base Case 2) Electricity network

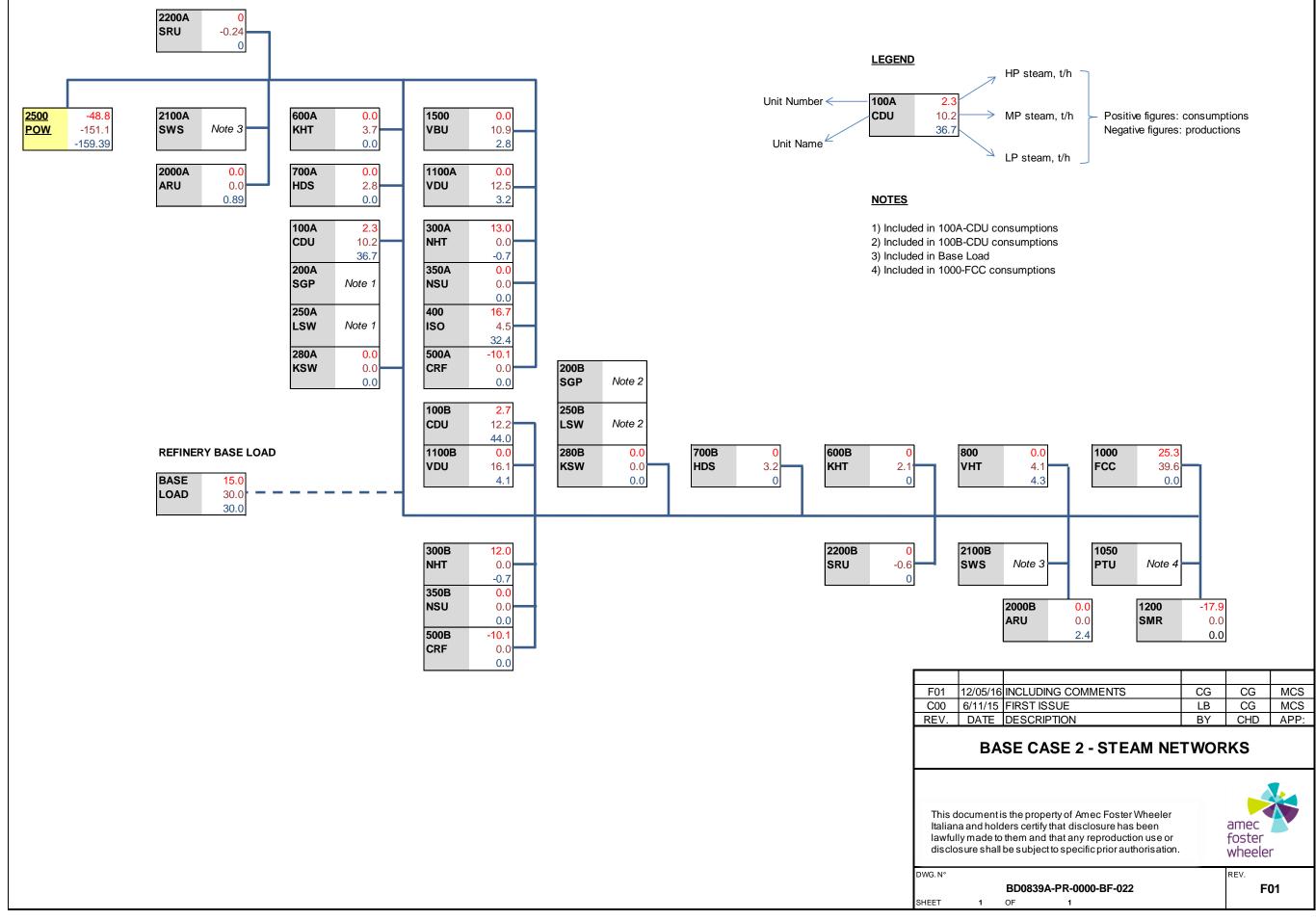


Figure 6-4: Base Case 2) Steam networks

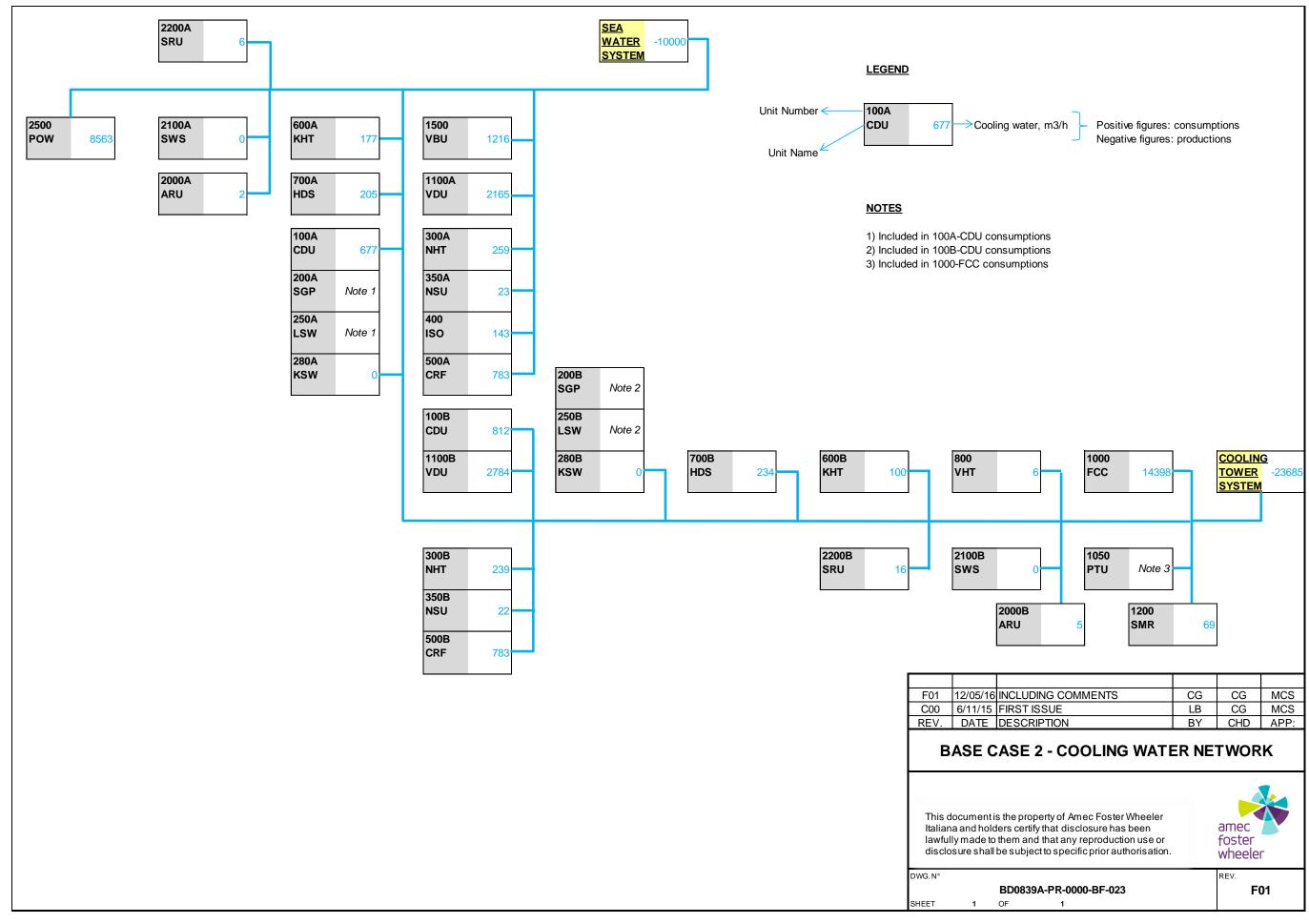


Figure 6-5: Base Case 2) Cooling water network

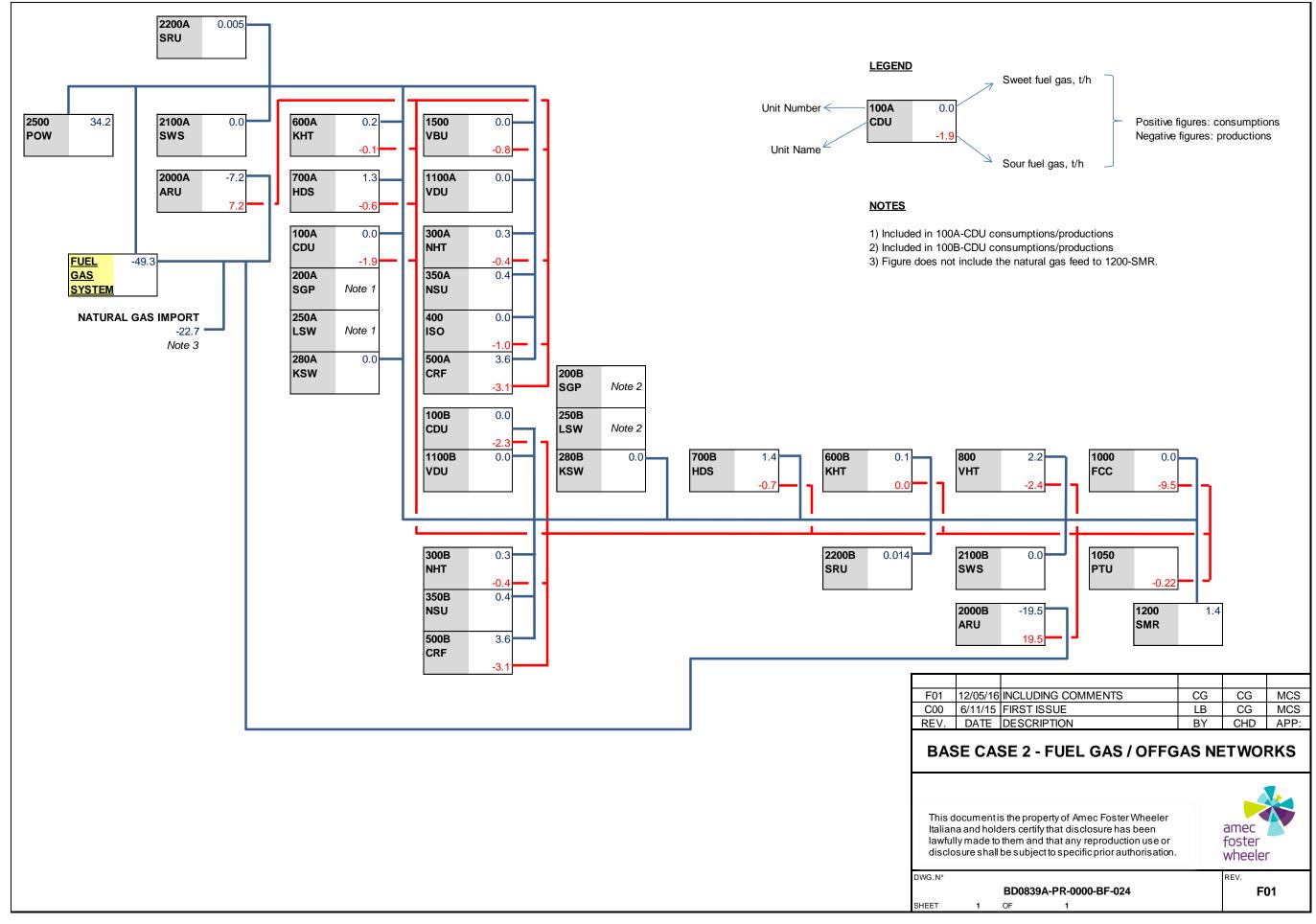


Figure 6-6: Base Case 2) Fuel Gas/Offgas networks

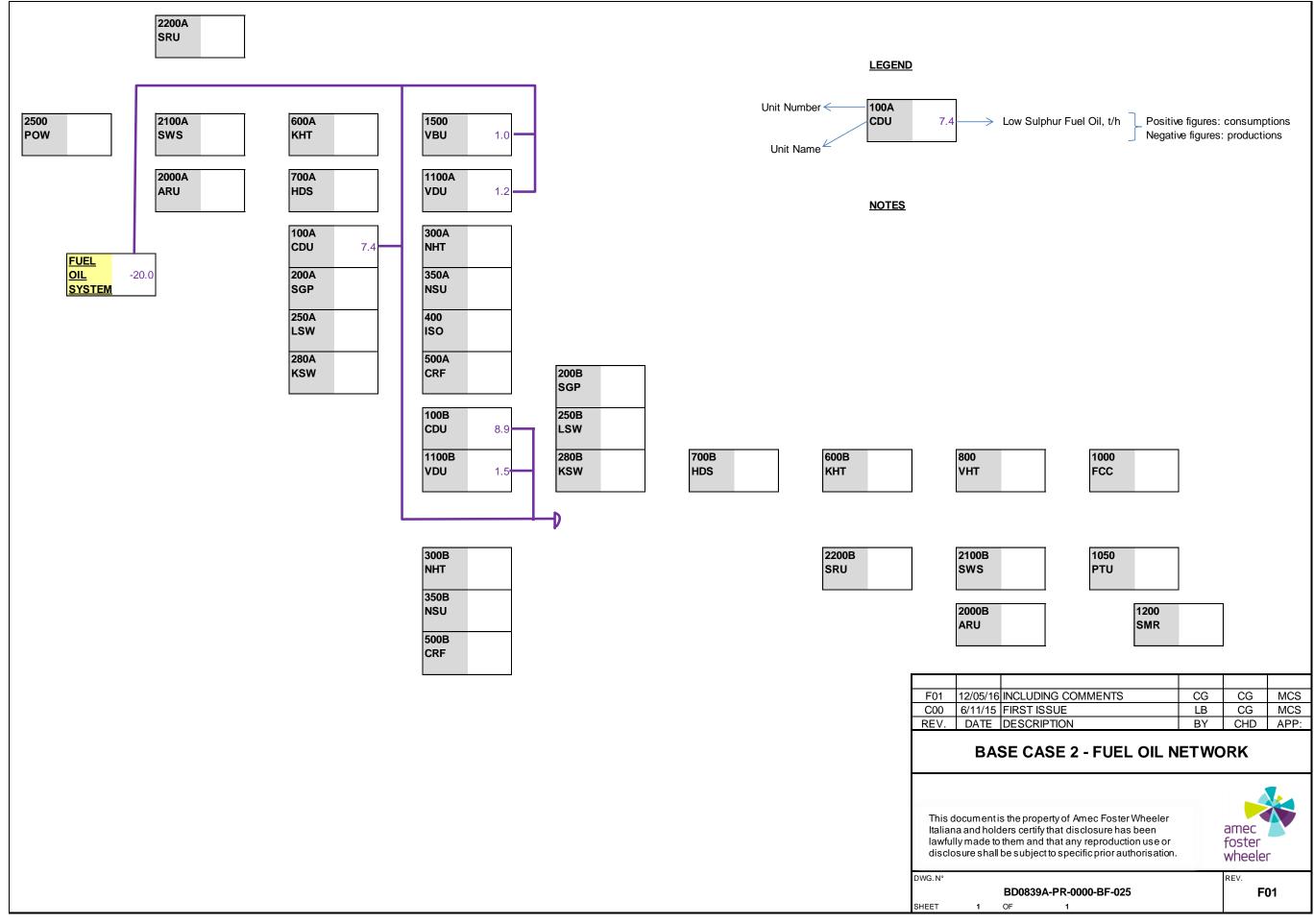


Figure 6-7: Base Case 2) Fuel oil network



## 6.4 Configuration of Power Plant

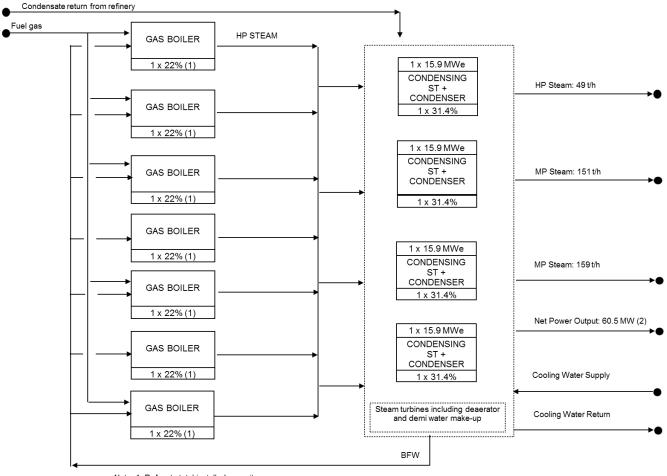
With respect of Base Case 1, the capacity and complexity increase of the refinery implies an increase in the steam and power demand, as shown in Table 6-6.

Power plant size has been increased following a modular approach: since Base Case 2 represents a stepup evolution of Base Case 1, the configuration of power plant has been also developed starting from the one described in paragraph 5.4, by adding new boilers and steam turbines of the same size to meet the new refinery power and steam demand.

As per Base Case 1, the power plant has been designed to be normally operated in balance with the grid and the refinery and such that no import/export of steam is required in normal operation. Also in this case, steam demand has higher priority over electricity demand, since refinery electrical demand can be provided by HV grid connection back-up.

Power plant configuration developed for Base Case 2 is shown in the following sketch.

#### BASE CASE 2



Note: 1. Refers to total installed capacity 2. Net with respect to internal power island consumptions

Figure 6-8: Base Case 2) Power Plant simplified Block Flow Diagram



Base Case 2 power plant major equipment number and size are summarized hereinafter:

- > 7 x 115 t/h Gas Boilers normally operated at 65% of their design load (corresponding to 74.7 t/h each)
- 4 x 20 MWe Condensing Steam Turbines normally operated at 79.6% of their design load (corresponding to 15.9 MWe each)

Power plant configuration has been conceived to have such an installed spare capacity both for power and steam generation to handle possible oscillations in power/steam from the users and to avoid refinery shutdown in case of equipment (boiler or steam turbine) trip.

In case one steam turbine trips, 95% of the total power demand is guaranteed by the remaining three steam turbines in operation: only a small import from the grid or load shedding is required in this scenario in order not to compromise the refinery normal operation.

Total installed spare capacity is summarized hereinafter:

- Gas Boilers (Steam) +54%
- Steam Turbines (Electric Energy) +26%



# 7. Base Case 3

### High Conversion Refinery - 220,000 BPSD Crude Capacity

The High Conversion Refinery, with respect of the Hydro-skimming Refinery described at paragraph 4.8, includes additional process units for the conversion of the Vacuum Gasoil (VGO) and of the Vacuum Residue into more valuable distillates (essentially gasoline and automotive diesel).

In Europe, the most wide-spread VGO conversion unit is the Fluid Catalytic Cracking (FCC) and so this unit is included in Base Case 3 (as in Base Case 2).

Upstream of the FCC, a Vacuum Gasoil Hydrotreating (VHT) unit is present to decrease the sulphur content of FCC feedstock, in order to respect  $SO_x$  limits at FCC stack.

For Vacuum Residue conversion, a Coker Unit is considered. It is considered to sell the fuel grade coke produced.

The FCC and Coker distillates are sent to finishing units to comply with the 10 ppm wt. sulphur specification for the automotive fuels.

The hydrogen from the Heavy Naphtha Catalytic Reformer is not enough to cover the overall hydrogen demand of the refinery. Therefore, a Steam Methane Reformer (SMR) is foreseen to close the hydrogen balance.

The overall configuration of Base Case 3 is considered as a step-up evolution of Base Case 1, both in terms of capacity and complexity increase. In other words, it is considered that, in a simple hydro-skimming refinery (as the one depicted as Base Case 1), a second crude distillation train (Atmospheric and Vacuum Distillation Units), FCC block (VHT+FCC+SMR) and DCU are built in a second phase. The consequent capacity increase of the gasoline block and the hydrotreating units is considered achieved by adding a second train in parallel to the original one.

The above assumption reflects the typical "life" of the European refineries, which have gradually expanded starting from an original nucleus. This results in the following main effects:

- Several units of the same type are running in parallel, resulting in a relatively good flexibility of the processing scheme (e.g. different feedstocks could be fed to each train) but also, on the other hand, in some inefficiencies (e.g. higher maintenance costs, lower energy efficiencies, etc.).
- Also the Power Plant in Base Case 3 is considered as an expansion of the facilities foreseen in Base Case 1, reflecting the "modular" expansion of the original refinery into a bigger, more complex and more demanding site.
- The increased demand of cooling water –with respect of cooling water consumption in Base Case 1- is considered to be satisfied by a closed loop circuit with cooling towers, working in parallel to the original open circuit of sea cooling water. As a matter of fact, for the upgrading of the refinery, it is assumed that more stringent environmental regulations have been met.
- Finally, also the layout of the Base Case 3 refinery reflects two main areas of units' allocation: beside the original nucleus of the older units (unit numbers identified with suffix –A), a second block of units is present and clearly identifiable (unit numbers identified with suffix –B). The FCC block and DCU are included in this newer portion of the refinery.



# 7.1 Refinery Balances

The balances developed for Base Case 3 are reported in the following tables and figures:

- Table 7-1: Base Case 3) Overall material balance
- ▶ Table 7-2: Base Case 3) Process units operating and design capacity
- ▶ Table 7-3: Base Case 3) Gasoline qualities
- Table 7-4: Base Case 3) Distillate qualities
- Table 7-5: Base Case 3) Fuel oil and bitumen qualities
- ▶ Table 7-6: Base Case 3) Main utility balance, fuel mix composition, CO2 emissions
- Figure 7-1: Base Case 3) Block flow diagrams with main material streams
- Table 7-7: Base Case 3) CO2 emissions per unit

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High Co	ReCAP Project reliminary Refinery Balances BASE CASE 3 onversion Refinery, 220,000 BPSD ERALL MATERIAL BALANCE	amec foster wheeler				
PRODUCTS	Annual Pro	duction, kt/y				
LPG	68	0.6				
Propylene	19	7.1				
Petrochemical Naphtha	20	0.6				
Gasoline U95 Europe		24.8				
Gasoline U92 USA Export	78	2.1				
Jet fuel	100	0.0				
Road Diesel	354	12.8				
Marine Diesel	47	472.4				
Heating Oil	70	8.6				
Low Sulphur Fuel Oil	20	9.8				
Medium Sulphur Fuel Oil	0	.0				
High Sulphur Fuel Oil	0	.0				
Bitumen	15	0.0				
Coke Fuel Grade	52	2.6				
Sulphur	89	9.3				
	Subtotal 103	80.7				
RAW MATERIALS	Consump	otions, kt/y				
Ekofisk	164	48.8				
Bonny Light		50.0				
Arabian Light		15.0				
Urals Medium		50.0				
Arabian Heavy		15.0				
Maya Blend (1)		6.0				
Imported Vacuum Gasoil		6.7				
МТВЕ		.0				
Natural Gas		6.1				
Biodiesel	22	1.4				
Ethanol	96	5.1				
		95.1				
	ki	t/y				
Fuels and Losses	81	4.4				

### Notes

1) Maya Blend consists of 50% wt. Maya crude oil + 50% wt. Arabian Light Crude Oil

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**REV.7** 12/05/2016

### ReCAP Project Preliminary Refinery Balances



### BASE CASE 3 High Conversion Refinery, 220,000 BPSD

### PROCESS UNITS OPERATING AND DESIGN CAPACITY

UNIT	Unit of measure	Design Capacity	Operating Capacity	Average Utilization
Crude Distillation Unit	BPSD	220000 (1)	220000 (1)	100%
Vacuum Distillation Unit	BPSD	86000 (1)	78604 (1)	91%
Naphtha Hydrotreater	BPSD	50000 (1)	48797	98%
Light Naphtha Isomerization	BPSD	15000	13774	92%
Heavy Naphtha Catalytic Reforming	BPSD	33000 (1)	31589	96%
Kero Sweetening	BPSD	15000 (1)	15000	100%
Kerosene Hydrotreater	BPSD	26000 (1)	24673	95%
Diesel Hydrotreater	BPSD	65000 (1)	65000	100%
Heavy Gasoil Hydrotreater	BPSD	50000	45154	90%
Fluid Catalytic Cracking	BPSD	60000	60000	100%
FCC Gasoline Hydrotreater	BPSD	24000	23128	96%
Delayed Coker	BPSD	35000	33807	97%
Sulphur Recovery Unit	t/d Sulphur	450 (1)	255	57%
Steam Reformer	Nm ³ /h Hydrogen	35000	31922	91%

#### Notes

1) Multiple units in parallel to be considered.

12/05/		ReCAP Proje eliminary Refinery BASE CASE onversion Refinery	Balances 3	fo	mec oster /heeler
EXCESS NAPH	ТНА	GASOLINE QUAL	<u>.ITIES</u>		
Component		Weight Quantit	y Weight Percent	Volume Quantity	Volume Percent
NAL	HT LIGHT NAPHTHA	104,352.2	1 52.031%	149,716.23	52.667%
LRF	LIGHT REFORMATE	31.1		44.00	
LCN	FCC LIGHT NAPHTHA treated	96,172.8		134,507.48	
		Total 200,556.2		284,267.71	
Quality		Blending Basis	s Value	Min	Max
RHO	DENSITY, KG/M3	VL	705.52		725.00
SPM	SULFUR, PPMW	WT	17.80		500.00
SPM VPR	VAPOR PRESSURE, KPA	WT VL	17.80 69.00		500.00 69.00
SPM	VAPOR PRESSURE, KPA	VL		Volume Quantity	
SPM VPR Unl. Premium	VAPOR PRESSURE, KPA	VL	69.00 y Weight Percent		69.00
SPM VPR Unl. Premium Component	(95) EU	VL Weight Quantit	69.00 y Weight Percent 3 0.721%	Quantity	69.00 Volume Percent
SPM VPR Unl. Premium Component BU# R10 ISO	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE	VL Weight Quantit 13,154.4	Weight Percent           3         0.721%           4         44.845%           4         15.738%	Quantity 22,519.42	69.00 Volume Percent 0.931% 40.821%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated	VL Weight Quantit 13,154.4 818,352.1 287,186.3 610,026.7	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%	Quantity 22,519.42 987,155.78 434,472.52 853,184.19	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%
SPM VPR Unl. Premium Component BU# R10 ISO	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL	VL Weight Quantit 13,154.4 818,352.1 287,186.3 610,026.7 96,125.2	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL	VL Weight Quantit 13,154.4 818,352.1 287,186.3 610,026.7	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%	Quantity 22,519.42 987,155.78 434,472.52 853,184.19	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL	VL Weight Quantit 13,154.4 818,352.1 287,186.3 610,026.7 96,125.2	69.00           y         Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8	69.00           y         Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           Value	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL           WT           VL	69.00           y         Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           x         Value           754.62         754.62	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR BEN	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL           WT           VL           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           Value           754.62         3.38           60.00         0.71	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           1.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH UN EOH RHO SPM VPR BEN ARO	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V AROMATICS, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL           WT           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           Value         754.62           3.38         60.00           0         0.71           3.2.03         32.03	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min 720.00	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           1.00           35.20
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL           WT           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           Value         754.62           3.38         60.00           0.711         32.03           91.02         91.02	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           1.00           35.20
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           S         Value           754.62         3.38           0         0.711           32.03         91.02           5.00         5.00	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min 720.00	69.00           Volume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           1.00           35.200           1.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00           10.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH Quality RHO SPM VPR BEN ARO E50 OXY OLE	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V AROMATICS, %V D86 @ 150°C, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           S         Value           754.62         3.38           60.00         0.711           32.03         91.02           5.00         14.53	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min 720.00	Kolume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           10.00           60.00           10.00           60.00           10.00           60.00           15.00           18.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY OLE EOH	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           Yalue           754.62           3.38         60.00           0.711         32.03           91.02         5.00           14.53         5.00	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min 720.00	Kolume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           10.00           60.00           10.00           60.00           10.00           60.00           15.00           15.00           15.00           15.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY OLE	VAPOR PRESSURE, KPA (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA treated ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, KPA BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OLEFINS, %V	VL           Weight Quantit           13,154.4           818,352.1           287,186.3           610,026.7           96,125.2           Total           1,824,844.8           Blending Basis           VL	Weight Percent           3         0.721%           4         44.845%           4         15.738%           0         33.429%           0         5.268%           0         100.000%           S         Value           754.62         3.38           60.00         0.711           32.03         91.02           5.00         14.53	Quantity 22,519.42 987,155.78 434,472.52 853,184.19 120,912.21 2,418,244.12 Min 720.00	Kolume Percent           0.931%           40.821%           17.966%           35.281%           5.000%           100.000%           Max           775.00           10.00           60.00           10.00           60.00           10.00           60.00           10.00           60.00           15.00           15.00           5.000

			ReCAP Project inary Refinery B BASE CASE 3 rsion Refinery, 2	alances	fo	mec oster heeler
Uni Promium	(02)	GAS	SOLINE QUALI	<u>ries</u>		
Unl. Premium	92)		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
BU#	C4 TO MOGAS/LPO	3	8,614.91	1.102%	14,748.10	1.399%
HRF	HEAVY REFORMA	TE	318.85	0.041%	376.45	0.036%
R10	<b>REFORMATE 100</b>		353,317.19	45.177%	426,196.85	40.430%
ISO	ISOMERATE		224,608.43	28.720%	339,800.95	32.234%
LCN	FCC LIGHT NAPHT	HA treated	195,216.97	24.961%	273,030.72	25.900%
		Total	782,076.34	100.000%	1,054,153.07	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3		VL	741.90	720.00	775.00
SPM	SULFUR, PPMW		WT	2.55		10.00
VPR	VAPOR PRESSUR	E, KPA	VL	60.00		60.00
BEN	BENZENE, %V		VL	0.69		1.00
ARO	AROMATICS, %V		VL	30.40		35.00
E50	D86 @ 150°C, %V		VL	91.10	75.00	
OXY	OXYGENATES, %\	/	VL	0.00		15.00
OLE	OLEFINS, %V		VL	11.01		18.00
EOH	ETHANOL, VOI%		VL	0.00		10.00
RON	Research		VL	92.41	92.00	
MON	Motor		VL	84.00	84.00	

<b>REV</b> 12/05/	Prelim	ReCAP Project inary Refinery B BASE CASE 3 rsion Refinery, 2	alances	f	amec oster vheeler
		<u>FILLATE QUALI</u>	TIES		
LPG PRODUCT	r 	Weight Quantity	Weight Percent	Volume	Volume Percent
•				Quantity	
LG#	LPG POOL Total	680,600.64 680,600.64	100.000% 100.000%	1,202,764.04 1,202,764.04	
Quality		Blending Basis	Value	Min	Max
SPM	SULFUR, PPMW	WT	5.00		140.00
VPR	VAPOR PRESSURE, KPA	VL	671.77	632.40	887.60
OLW	OLEFINS, %W	WT	2.56		30.00
Jet Fuel EU					
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
KED	HT KERO	333,008.43	33.301%	419,670.36	33.457%
KMCR4	KERO FROM MEROX URALS	493,264.17	49.326%	617,351.90	49.217%
KMCR5	KERO FROM MEROX AR. HVY	120,785.00	12.079%	150,981.25	12.037%
KMCR6	KERO FROM MEROX MAYA	52,942.40 1,000,000.00	5.294% 100.000%	66,343.86 1,254,347.37	
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	797.23	775.00	840.00
SUL	SULFUR, %W	WT	0.14	110.00	0.30
FLC	FLASH POINT, °C (PM, D93)	VL	40.00	38.00	
Diesel EU					
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
LCO	LIGHT CYCLE OIL treated	394,124.38	11.125%	414,867.77	9.895%
HCN	FCC HEAVY NAPHTHA	134,746.57	3.803%	158,525.38	
KED	HT KERO	744,173.47	21.005%	937,836.76	
DLG	DESULF LGO	2,048,398.35	57.818%	2,429,891.28	
FAM	BIODIESEL	221,373.62 3,542,816.39	6.249% 100.000%	251,560.93 4,192,682.11	6.000% 100.000%
Quality		Planding Pasia	Value	Min	Max
Quality		Blending Basis	Value	Min	Мах
RHO	DENSITY, KG/M3	VL	845.00	820.00	
SPM	SULFUR, PPMW	WT	8.96		10.00
FLC	FLASH POINT, °C (PM, D93)	VL	55.00	55.00	
CIN	CETANE INDEX D4737	VL	46.86	46.00	
V04	VISCOSITY @ 40°C, CST	WT	2.45	2.00	
E36	D86 @360°C, %V	VL	97.48	95.00	
FAM	BIODIESEL CONTENT, %VOL	VL	6.00	6.00	7.00

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12/05/	2016		ReCAP Project nary Refinery Ba BASE CASE 3 rsion Refinery, 2	alances	f	amec Toster wheeler
Heating Oil		DIST	TILLATE QUALI	ITIES		
Heating Oil Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
HCN	FCC HE	AVY NAPHTHA	229,656.16	32.412%	270,183.72	32.363%
LGCR3		AB.LIGHT	36,429.59	5.141%	42,707.61	
LGCR1	LGO EK		300,582.21	42.421%	354,042.65	
VLG		LGO ex VHT	141,895.31	20.026%	167,923.45	
		Total	708,563.28	100.000%	834,857.43	
Quality			Blending Basis	Value	Min	Max
DUIO	DENOT		VL	848.72	815.00	860.00
RHO	DENSI		VL			
	DENSIT SULFUF		WT	1,000.00	010.00	1,000.00
SPM	SULFUF	PPMW POINT, °C (PM, D93)			55.00	,
SPM	SULFUF FLASH	R, PPMW	WT	1,000.00		
RHO SPM FLC CIN V04	SULFUF FLASH CETANE	r, PPMW Point, °C (PM, D93)	WT VL	1,000.00 55.00	55.00	
SPM FLC CIN V04 MARINE DIESE	SULFUF FLASH CETANE VISCOS	R, PPMW POINT, °C (PM, D93) E INDEX D4737	WT VL VL	1,000.00 55.00 48.11 2.65	55.00 40.00	6.00
SPM FLC CIN V04 MARINE DIESE Component	SULFUF FLASH CETANE VISCOS	R, PPMW POINT, °C (PM, D93) E INDEX D4737	WT VL VL WT	1,000.00 55.00 48.11 2.65	55.00 40.00 2.00 Volume	6.00 Volume Percent
SPM FLC CIN V04 MARINE DIESE Component LCO	SULFUF FLASH CETANE VISCOS	R, PPMW POINT, °C (PM, D93) E INDEX D4737 ITY @ 40°C, CST	WT VL VL WT	1,000.00 55.00 48.11 2.65 Weight Percent	55.00 40.00 2.00 Volume Quantity	6.00 Volume Percent 8.393%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN	SULFUF FLASH CETANE VISCOS	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA	WT VL VL WT Weight Quantity 43,142.22	1,000.00 55.00 48.11 2.65 Weight Percent 9.133%	55.00 40.00 2.00 Volume Quantity 45,412.87	6.00 Volume Percent 8.393% 18.765%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LCO HCN LGCR2	LIGHT C FCC HE LIGO BC	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA	WT VL VL WT Weight Quantity 43,142.22 86,305.52	1,000.00 55.00 48.11 2.65 Weight Percent 9.133% 18.271%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91	6.00 Volume Percent 8.393% 18.765% 69.144%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LGCR2 LGCR3	LIGHT C FLC HE LIGHT C FCC HE LGO AR	R, PPMW POINT, °C (PM, D93) EINDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA INNY	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15	1,000.00 55.00 48.11 2.65 Weight Percent 9.133% 18.271% 68.986%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LCO HCN LGCR2 LGCR3	LIGHT C FLC HE LIGHT C FCC HE LGO AR	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA INNY AB.LIGHT	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09	1,000.00 55.00 48.11 2.65 Weight Percent 9.133% 18.271% 68.986% 3.329%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LCO HCN LGCR2 LGCR3	LIGHT C FLC HE LIGHT C FCC HE LGO AR	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA NNY AB.LIGHT LGO ex VHT	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09 1,330.54	1,000.00 55.00 48.11 2.65 Weight Percent 9.133% 18.271% 68.986% 3.329% 0.282%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LGCR2 LGCR3 VLG Quality	LIGHT C FLASH CETANE VISCOS LIGHT C FCC HE LGO BC LGO AR DESULF	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA NNY AB.LIGHT LGO ex VHT	WT VL VL WT WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09 1,330.54 472,375.52	1,000.00 55.00 48.11 2.65 Weight Percent 9.133% 18.271% 68.986% 3.329% 0.282% 100.000%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60 541,094.06	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%           100.000%           Max
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LGCR2 LGCR3 VLG Quality RHO	LIGHT C FCC HE UGO AR DESULF	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA NNY AB.LIGHT LGO ex VHT Total	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09 1,330.54 472,375.52 Blending Basis	1,000.00         55.00         48.11         2.65         Weight Percent         9.133%         18.271%         68.986%         3.329%         0.282%         100.000%	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60 541,094.06	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%           100.000%           Max           890.00
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LGCR2 LGCR3 VLG Quality RHO SPM	LIGHT C FCC HE UGO AR DESULF	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA NNY AB.LIGHT LGO ex VHT Total Y, KG/M3	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09 1,330.54 472,375.52 Blending Basis VL	1,000.00         55.00         48.11         2.65         Weight Percent         9.133%         18.271%         68.986%         3.329%         0.282%         100.000%         Value         873.00	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60 541,094.06	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%           100.000%           Max           890.00           1,000.00
SPM FLC CIN V04 MARINE DIESE Component LCO HCN LGCR2 LGCR3 VLG	LIGHT C FLASH CETANE VISCOS LIGHT C FCC HE LGO BC LGO AR DESULF DENSIT SULFUF FLASH	R, PPMW POINT, °C (PM, D93) INDEX D4737 ITY @ 40°C, CST YCLE OIL treated AVY NAPHTHA NNY AB.LIGHT CLGO ex VHT Total Y, KG/M3 R, PPMW	WT VL VL WT Weight Quantity 43,142.22 86,305.52 325,872.15 15,725.09 1,330.54 472,375.52 Blending Basis VL WT	1,000.00         55.00         48.11         2.65         Weight Percent         9.133%         18.271%         68.986%         3.329%         0.282%         100.000%         Value         873.00         1,000.00	55.00 40.00 2.00 Volume Quantity 45,412.87 101,535.91 374,135.65 18,435.04 1,574.60 541,094.06 Min	6.00           Volume Percent           8.393%           18.765%           69.144%           3.407%           0.291%           100.000%           Max           890.00           1,000.00

REV 12/05/ Low Sulphur F	2016	High Conve	ReCAP Project nary Refinery Ba BASE CASE 3 rsion Refinery, 2 L / BITUMEN QI	alances 20,000 BPSD	f	oster vheeler
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
SLU	FCC SLL	JRRY OIL	231,363.57	62.137%	243,540.60	62.137%
lco	LIGHT C	YCLE OIL untreated	140,981.25	37.863%	148,401.31	37.863%
		Total	372,344.82	100.000%	391,941.92	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY	′, KG/M3	VL	950.00		991.00
SUL	SULFUR	, %W	WT	0.36		0.50
FLC	FLASH F	POINT, °C (PM, D93)	VL	119.54	66.00	
V05	VISCOSI	TY @ 50°C, CST	WT	17.10		380.00
CCR	CONRAD	DSON CARBON RES, %W	WT	0.00		15.00
BITUMEN						
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
VDCR5	VDU RES	S MIX5	23,814.30	15.876%	23,462.36	16.112%
VDCR6	VDU RE	S MIX6	126,185.70	84.124%	122,154.60	83.888%
		Total	150,000.00	100.000%	145,616.96	100.000%

Table 7-6: Base Case 3) Main utility balance, fuel mix composition,  $CO_2$  emissions

<b>REV.7</b> 12/05/2016						amec foster wheeler		
		<u>Main u</u>	TILITY BALA	NCE				
	<b>FUEL</b> Gcal/h	POWER kW	HP STEAM tons/h	MP STEAM tons/h	LP STEAM tons/h	COOLING WATER (2) m3/h	RAW WATER m3/h	
MAIN PROCESS UNITS	580	40870	37	114	131	28362	1110/11	
BASE LOAD	500	22500	15	30	30	20002		
POWER PLANT	345	-68583	-52	-144	-161	2089		
SEA WATER SYSTEM	0.10	1712				-10000		
COOLING TOWER SYSTEM		3501				-20452		
TOTAL	924	0	0	0	0	0	2260	
REFINERY FUEL GAS LOW SULPHUR FUEL OIL (3) FCC COKE NATURAL GAS to fuel system	39.1 19.3 14.5 1.9	328.8 162.5 121.7 16.3	46% 23% 17% 2%					
NATURAL GAS to gas turbine	9.5	79.4	11%					
TOTAL	84.4	708.7						
		<u>CO2</u>	2 EMISSIONS	<u>5</u>				
	t/h							
From Steam Reformer	25.5	1						
From FG/NG combustion	137.5	-						
From FO combustion	61.9	1						
From FCC coke combustion	53.1	1						
TOTAL	278.0	correspon	ding to	2334.8 222.5	kt/y kg CO2 / t cr	ude		
<b>Notes</b> 1) (-) indicates productions 2) 10°C temperature increase ha 3) LSFO is burnt in CDU and VE		sidered						

**REV.7** 12/05/2016

**ReCAP Project** 

#### **Overall Refinery Balance**

BASE CASE 3

High Conversion Refinery, 220,000 BPSD

### **BLOCK FLOW DIAGRAM**

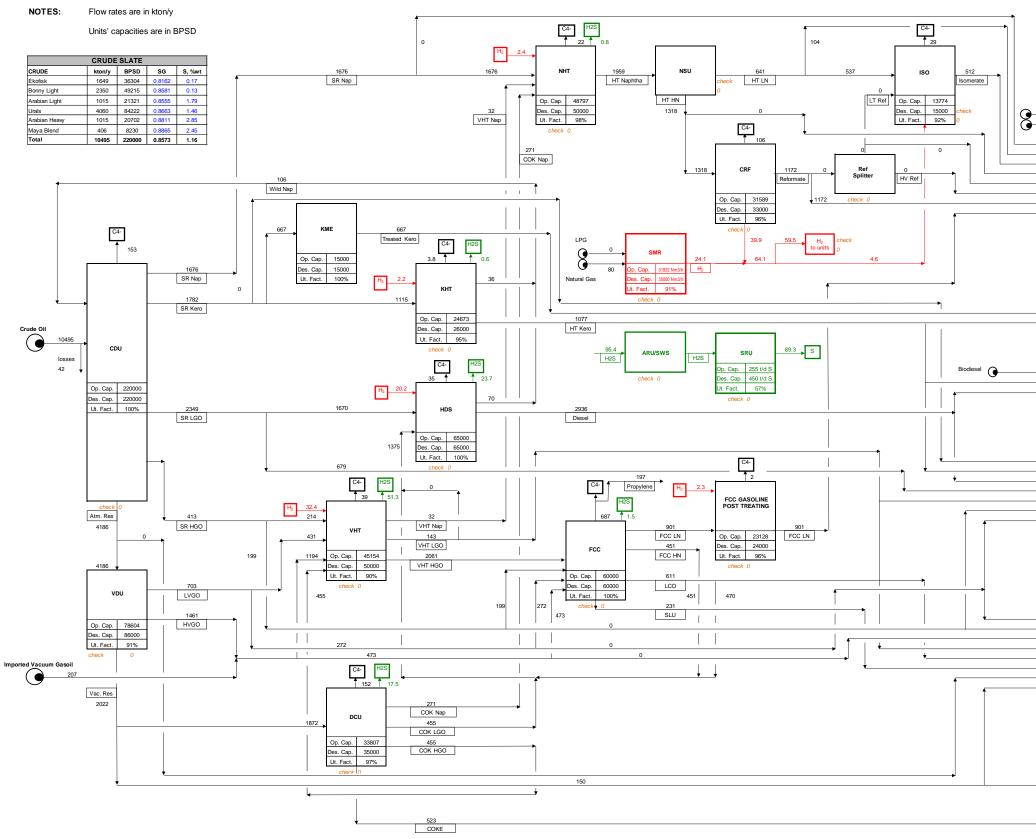


Figure 7-1: Base Case 3) Block flow diagrams with main material streams

	LPG
Propane	121
Butane	560
Total prod.	681
To SMR	0
To fuel	0
Sales	681

	Propylene
Propylene	197
Sales	197

	U 95-EU	U 92-US	Excess Naph.	тот
MTBE	0	0	0	0
Ethanol	96	0	0	96
Butanes	13	9	0	22
SR Naphtha	0	0	0	0
HT Light Naphtha	0	0	104	104
Isomerate	287	225	0	512
HT Heavy Naphtha	0	0	0	0
LT Reformate	0	0	0	0
HV Reformate	0	0	0	0
Reformate	818	353	0	1172
FCC LN	610	195	96	901
Sales	1825	782	201	2807

Jet Fuel
667
333
1000
•
Diesel
221
744
2577
25//
25/7

		Heating Oil	Mar. Dies.	тот
	SR Kero	Ö	Ū	0
	HT Kero	0	0	0
5	Diesel	230	129	359
ļ	SR LGO	337	342	679
Ĩ	VHT LGO	142	1	143
	SR HGO	Ö	0	0
Ĵ	SR LVGO	0	0	0
	Sales	709	472	1181

		LSFO	MSFO	HSFO	TOT
	SR LVGO	0	Ö	0	0
	SR HGO	0	0	0	0
	SR HVGO	0	Ö	0	0
ĺ	VHT LGO	Ö	Ö	Ö	0
	LCO untreated	141	0	0	141
	SLU	231	Ö	0	231
Ĵ	Atm. Residue	0	0	0	0
	Vac. Residue	Ö	Ö	Ö	0
	Total prod.	372	0	0	372
	To RFO	163	-	-	163
	Sales	210	0	0	210

	Bitumen
Vac. Res.	150
Sales	150
	Coke
Coke Fuel Grade	Coke 523

	Sulphur
Sulphur	89
Sales	89

#### REV.7 12/05/2016

**ReCAP** Project 1-BD-0839A

#### CO₂ EMISSION PER UNIT - BASE CASE 3

					PROCESS	UNITS								
		UNIT		Desire Constitu	Operatin	g Fuel Consum	ption [t/h]	Operat	ing CO ₂ Emiss	ion [t/h]	% on Total	CO ₂ concentr.	Operating	Notes
			Unit of measure	Design Capacity	Fuel Gas	Fuel Oil	Coke	Fuel Gas	Fuel Oil	Coke	CO ₂ Emission	in flue gases, vol %	Temperature [°C]	(1)
0100A	CDU	Crude Distillation Unit	BPSD	100000	-	7.4	-	-	23.8	-	8.5%	11.3%	200 ÷ 220	
0100B	CDU	Crude Distillation Unit	BPSD	120000	-	8.9	-	-	28.5	-	10.3%	11.3%	200 ÷ 220	(2)
0300A	NHT	Naphtha Hydrotreater	BPSD	23000	0.34	-	-	0.9	-	-	0.3%	8.1%	420 ÷ 450	(2)
0350A	NSU	Naphtha Splitter Unit	BPSD	23000	0.40	-	-	1.1	-	-	0.4%	8.1%	420 - 450	(3)
0300B	NHT	Naphtha Hydrotreater	BPSD	27000	0.31	-	-	0.8	-	-	0.3%	8.1%	420 ÷ 450	(3)
0350B	NSU	Naphtha Splitter Unit	BPSD	27000	0.37	-	-	1.0	-	-	0.4%	8.1%	420 - 430	(3)
0500A	CRF	Catalytic Reforming	BPSD	15000	3.6	-	-	10.0	-	-	3.6%	8.1%	180 ÷ 190	
0500B	CRF	Catalytic Reforming	BPSD	18000	3.6	-	-	10.0	-	-	3.6%	8.1%	180 ÷ 190	
0600A	KHT	Kero HDS	BPSD	14000	0.2	-	-	0.6	-	-	0.2%	8.1%	420 ÷ 450	
0600B	KHT	Kero HDS	BPSD	12000	0.1	-	-	0.4	-	-	0.1%	8.1%	420 ÷ 450	
0700A	HDS	Gasoil HDS	BPSD	26000	1.2	-	-	3.3	-	-	1.2%	8.1%	420 ÷ 450	
0700B	HDS	Gasoil HDS	BPSD	39000	1.6	-	-	4.4	-	-	1.6%	8.1%	420 ÷ 450	
0800	VHT	Vacuum Gasoil Hydrotreater	BPSD	50000	2.8	-	-	7.7	-	-	2.8%	8.1%	200 ÷ 220	
1000	FCC	Fluid Catalytic Cracking	BPSD	60000	-	-	14.5	-	-	53.1	19.1%	16.6%	300 ÷ 320	
1100A	VDU	Vacuum Distillation Unit	BPSD	35000	-	1.2	-	-	3.9	-	1.4%	11.3%	380 ÷ 400	
1100B	VDU	Vacuum Distillation Unit	BPSD	51000	-	1.8	-	-	5.7	-	2.1%	11.3%	200 ÷ 220	(2)
1200	SMR	Steam Reformer		35000	2.1	-	-	5.8	-	-	2.1%	8.1%	125 - 160	(4)
1200	SIVIK	Steam Reformer Feed	Nill /II Hydrogen	30000	9.6	-	-	25.5	-	-	9.2%	24.2%	135 ÷ 160	(4)
1400	DCU	Delayed Coking	BPSD	35000	4.4	-	-	11.9	-	-	4.3%	8.1%	200 ÷ 220	
		·				Sub Tota	Process Units	8	198.5		71.4%			

	AUXILIARY UNITS													
2200A	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	55	0.005	-	-	0.01	-	-	0.0%	< 8%	380 ÷ 400	
2200B	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	2 x 197.5	0.030	-	-	0.08	-	-	0.0%	< 8%	380 ÷ 400	
						Sub Tota	al Auxiliary Units		0.10		0.0%			

					POWER	UNITS								
2500	POW	Power Plant - Gas Turbine	6347	78000	9.5	-	-	25.1	-	-	9.0%	3.2%	115 ÷ 140	
2500	POW	Power Plant - HRSG + Steam Boilers	KVV	78000	19.9	-	-	54.3	-	-	19.5%	8.1%	115 ÷ 140	
						Sub To	tal Power Units		79.5		28.6%			

		278.0	TOTAL CO ₂ EMISSION
<b>50% 22% 1</b>	19%	50% 22%	5

#### Notes

(1) Fuel gas is a mixture of refinery fuel gas (95%) and imported natural gas (5%).

(1) Fuergas is a mixture of remery hergas (30%) and imported natural gas (3%).
(2) In train B, Crude and Vacuum Distillation heaters (units 0100B and 1100B) have a common stack.
(3) Both in train A and B, Naphtha Hydrotreater and Naphtha Splitter heaters (units 0300A/0350A and 0300B/0350B) have a common stack.
(4) Only natural gas is used as feed to the Steam Reformer, unit 1200; after reaction and hydrogen purification, tail gas and fuel gas are burnt in the Steam Reformer furnace.



100%	



# 7.2 Refinery Layout

The layout of the Base Case 3 refinery has been developed starting from the plot plan of Base Case 1, essentially by adding a second block of process units beside the original nucleus of the refinery.

As already mentioned, this approach reflects the assumption of a refinery expanded, over its life, both in terms of capacity and complexity.

Also some auxiliary, utility and offsite systems, like for example the Waste Water Treatment (WWT) and the Flare, have been duplicated in the final configuration of the site.

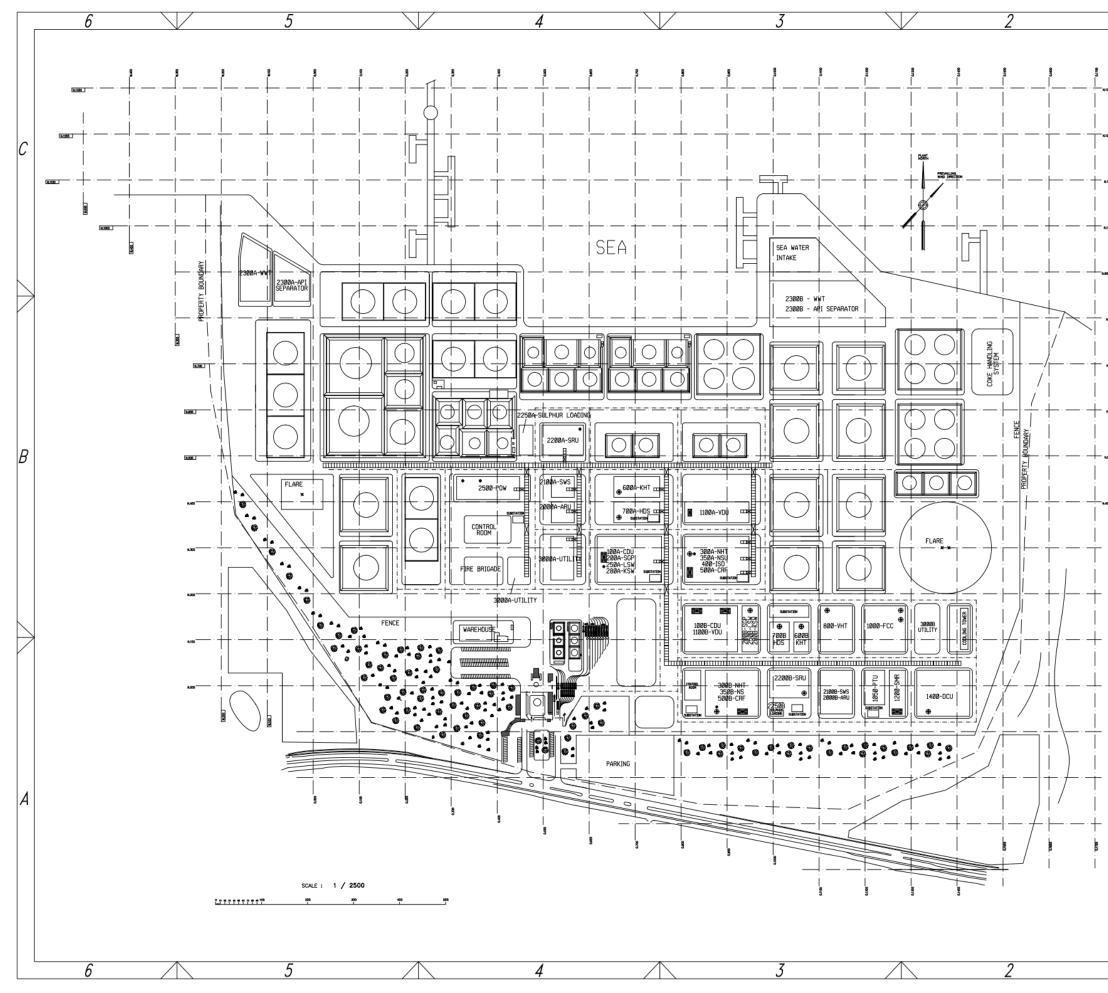


Figure 7-2: Base Case 3) Refinery layout

	~			
	/		1	
			UNIT LIST	
	UN	IT	DESCRIPTION	1
		188A	CRUDE DISTILLATION (CDU)	
		1100A	VACUUM DISTILLATION (VDU)	
		200A	SATURATED GAS PLANT (SGP)	
		25ØA	LPG SWEETENING (LSW)	
		200B	SATURATED GAS PLANT (SGP)	
		25ØB	LPG SWEETENING (LSW)	1
		28ØA	KERO SWEETENING (KSW)	
		2808	KERO SWEETENING (KSW)	
,		300a	NAPHTHA HYDROTREATER (NHT)	
		300B	NAPHTHA HYDROTREATER (NHT)	
		35ØA	NAPHTHA SPLITTER (NSU)	1
	PROCESS UNITS	400	ISOMERIZATION (ISO)	
,	ESS	35ØB	NAPHTHA SPLITTER (NSU)	
	PROCI			
	-	500A	CATALYTIC REFORMING (CRF)	
		500B	CATALYTIC REFORMING (CRF)	
		600A	KERO HDS (KHT))	
		600B	KERO HDS (KHT))	$\swarrow$
			GASOIL HDS (HDS)	$\setminus$
		700A		
		700B	GASOIL HDS (HDS)	
		800	VACUUM GASOIL HYDROTREATER (VHT)	
		1000	FLUID CATALYTIC CRACKING (FCC)	
•		1050	FCC GASOLINE POST-TREATMENT UNIT (PTU)	
		1008	CRUDE DISTILLATION (CDU)	
		1100B	VACUUM DISTILLATION (VDU)	
8		1200	STEAM REFORMING (SMR)	
		1400	DELAYED COKING (DCU)	
		2000A	AMINE WASHING AND REGENERATION (ARU)	
		20008	AMINE WASHING AND REGENERATION (ARU)	B
		2100A	SOUR WATER STRIPPER (SWS)	
		2100B	SOUR WATER STRIPPER (SWS)	1
			SULPHUR RECOVERY (SRU)	
		2200A		
			TAIL GAS TREATMENT	
	UNITS	22008	SULPHUR RECOVERY (SRU)	
	ARY I		TAIL GAS TREATMENT	
	AUXILIARY	225ØA	SULPHUR LOADING	
		225ØB	SULPHUR LOADING	
			WASTE WATER TREATMENT (WWT)	1
		238ØA	API SEPARATOR	
		2300B	WASTE WATER TREATMENT (WWT)	
			API SEPARATOR	
	POWER	2500	POWER PLANT (POW)	$\setminus$
	집공			
		3000A	UTILITY UNITS	
		3000B	UTILITY UNITS	
		4000	OFF SITES UNITS	1
				Δ
				A
				A
			<u></u>	A
		9/11/1		A
		0/11/1 DATE	DESCRIPTION BY CHD APP. REVISIONS	A
	REV.	DATE	APPROVED FOR CAND APP.	A
	REV.	DATE	DESCRIPTION BY CHD APP. REVISIONS	A
	REV.	DATE	ASSAME         #         -00         APV.           ROSALE         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER           FOSTER         Wheeler         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER           OPERATION         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER         APPROVED FOR EXAMENDER	A
	REV.	DATE		A
	an	nec	RESERVE         P         OP         APY           FOSTER         Non-Rev.         APPROVED FOR EXAMPLE.         <	A
	an	nec	RESERVE         P         OP         APY           FOSTER         Non-Rev.         APPROVED FOR EXAMPLE.         <	
	an		ASCONTINU         M         OB         MVL           RESCORE         APPENDED FOR DOWNERS.LICH.           CONTRACT OF DOWNERS.LICH.           CONTRACT of DOWNERS.LICH.	
	an		RESERVE         P         OP         APY           FOSTER         Non-Rev.         APPROVED FOR EXAMPLE.         <	
	an		ASCONTINU         M         OB         MVL           RESCORE         APPENDED FOR DOWNERS.LICH.           CONTRACT OF DOWNERS.LICH.           CONTRACT of DOWNERS.LICH.	



# 7.3 Main Utility Networks

The main utility balances have been reported on block flow diagrams, reflecting the planimetric arrangement of the process units and utility blocks.

In particular, the following networks' sketches have been developed:

- Figure 7-3: Base Case 3) Electricity network
- Figure 7-4: Base Case 3) Steam networks
- Figure 7-5: Base Case 3) Cooling water network
- Figure 7-6: Base Case 3) Fuel Gas/Offgas networks
- Figure 7-7: Base Case 3) Fuel oil network

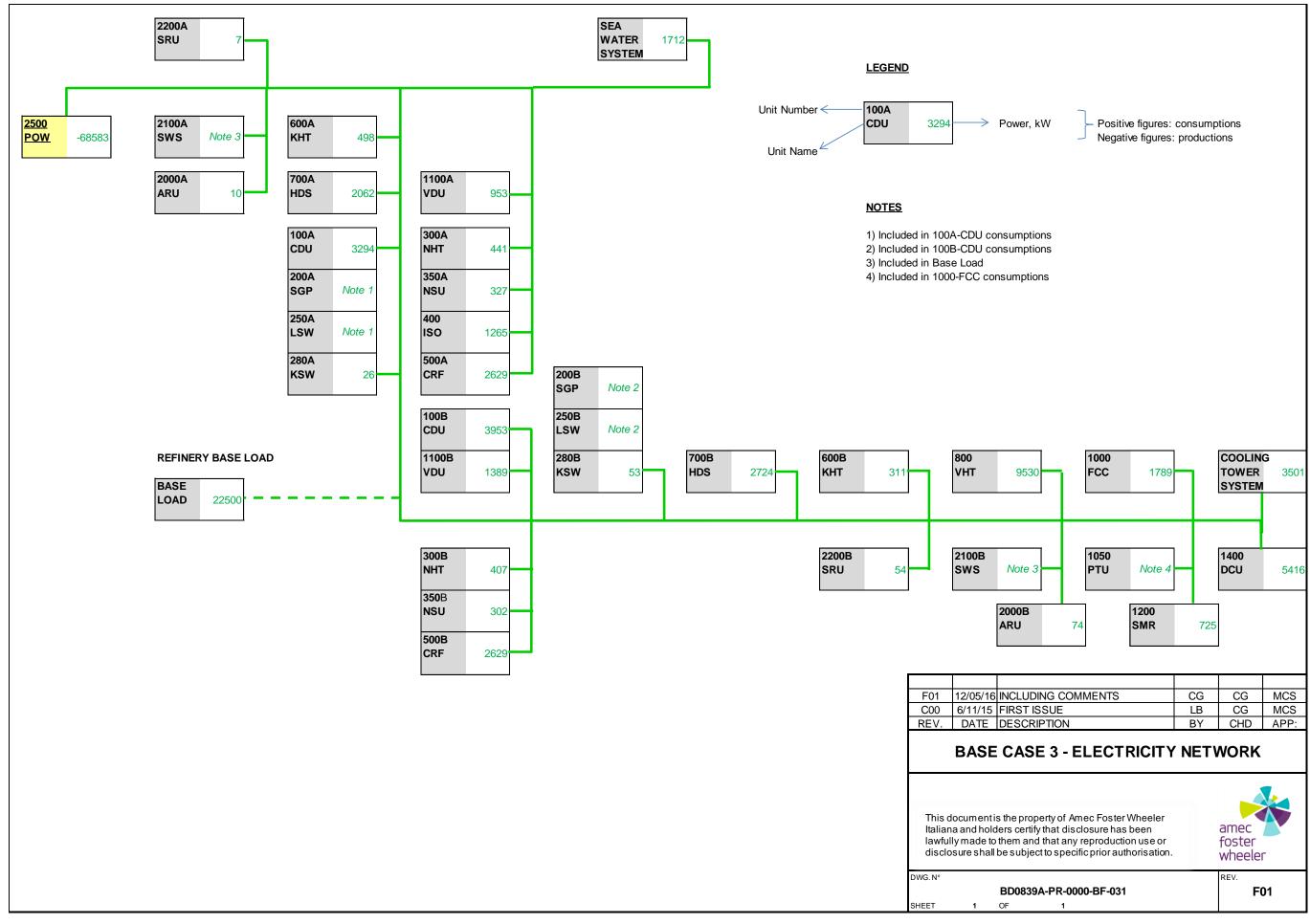


Figure 7-3: Base Case 3) Electricity network

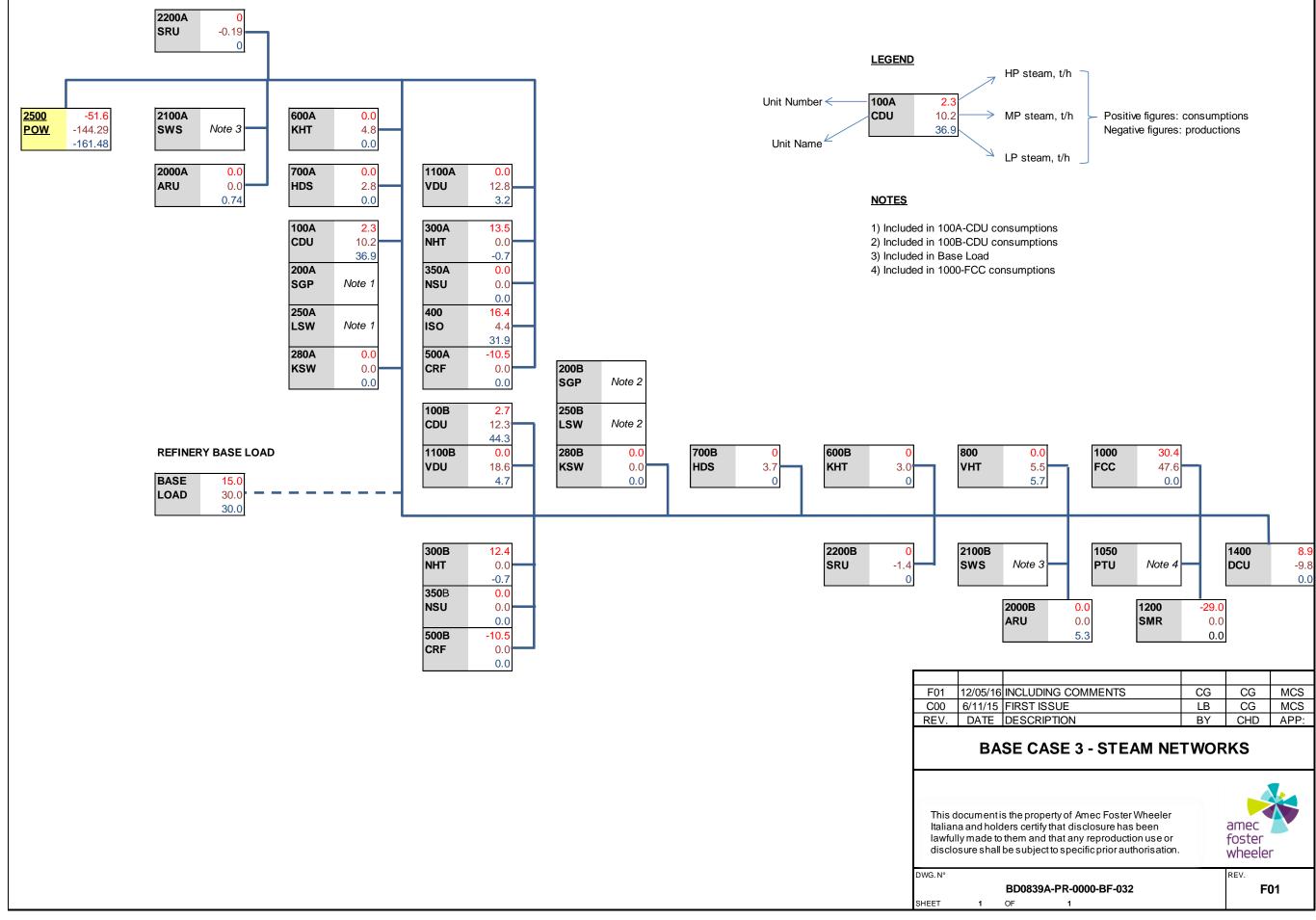


Figure 7-4: Base Case 3) Steam networks

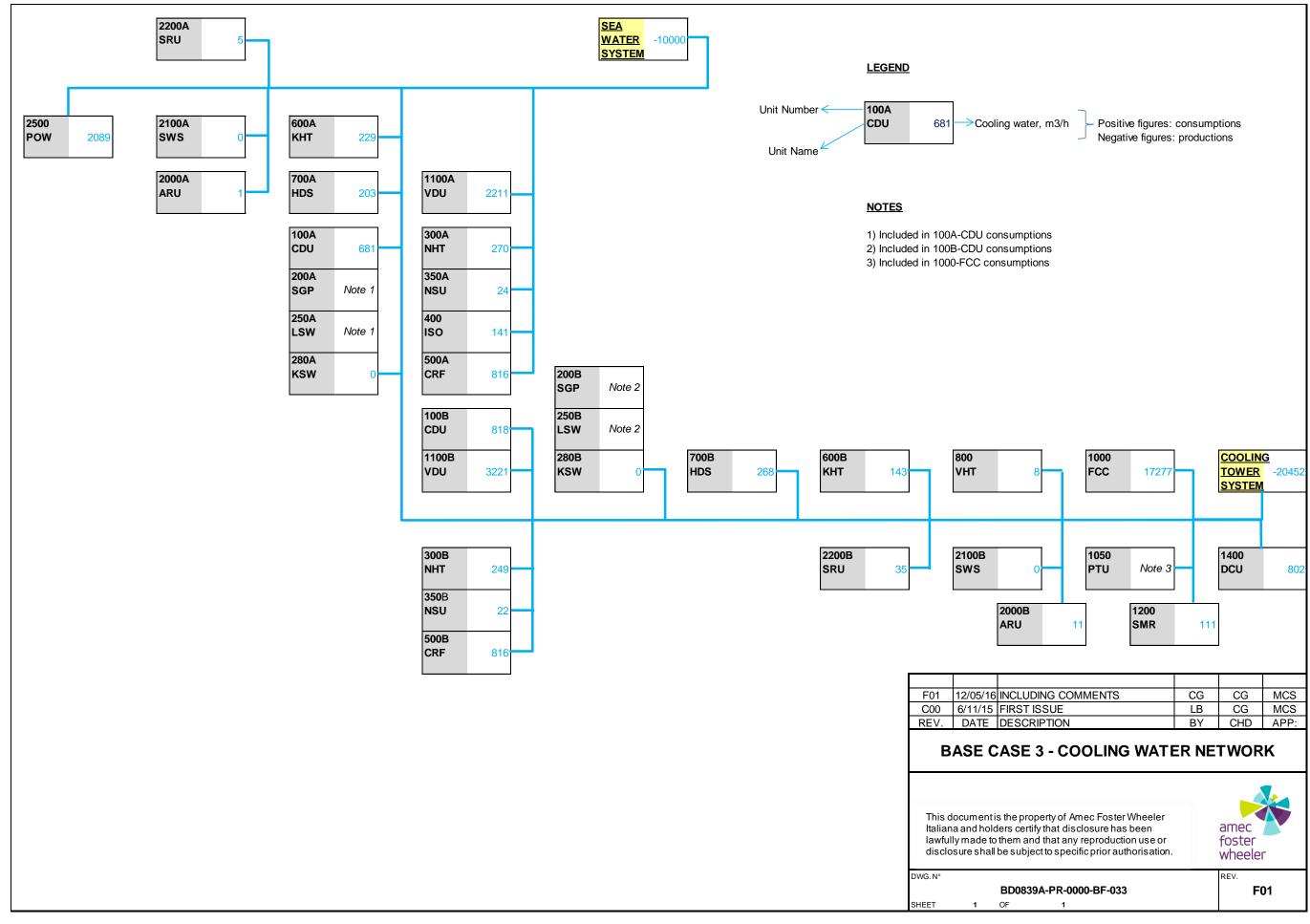


Figure 7-5: Base Case 3) Cooling water network

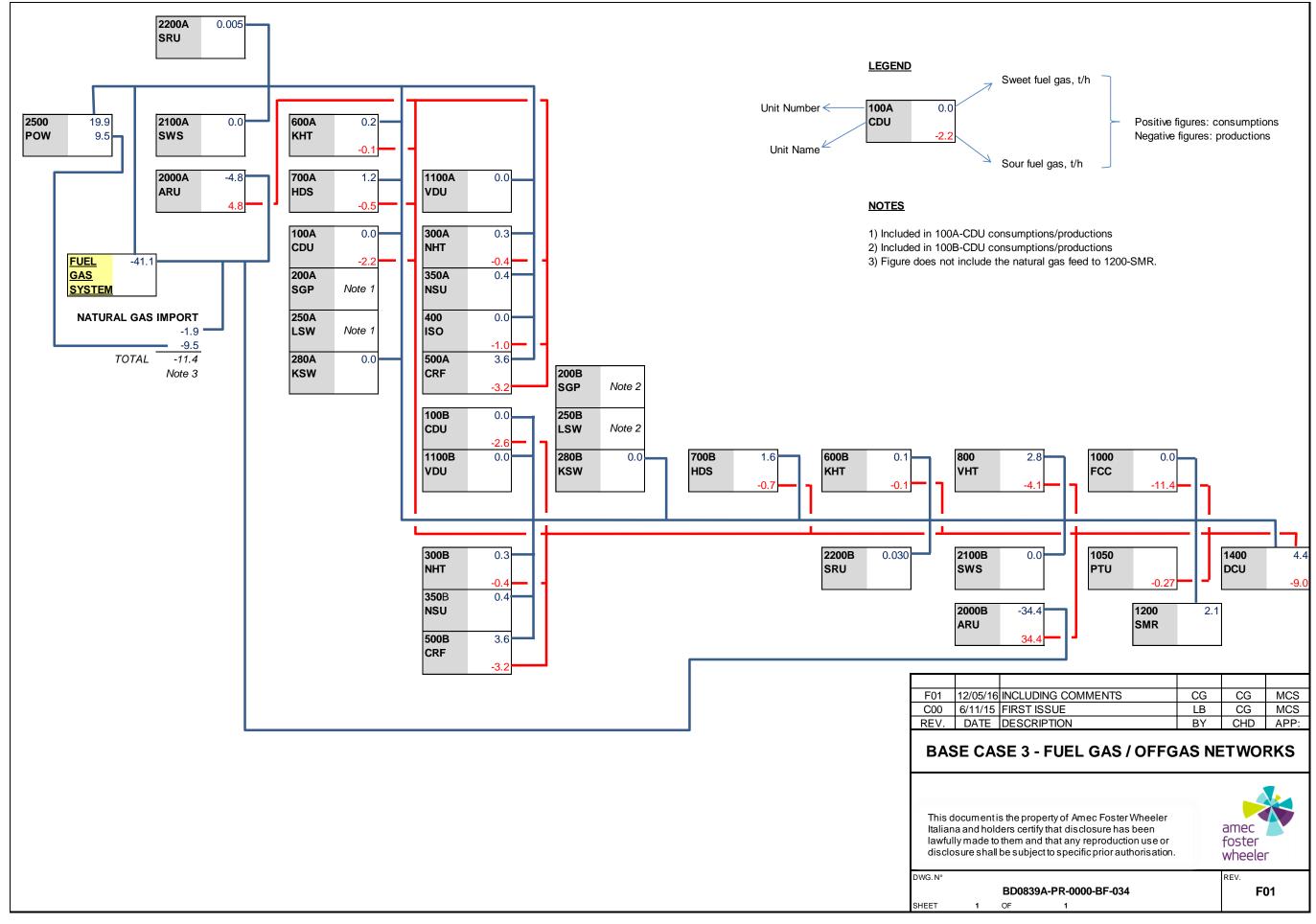


Figure 7-6: Base Case 3) Fuel Gas/Offgas networks

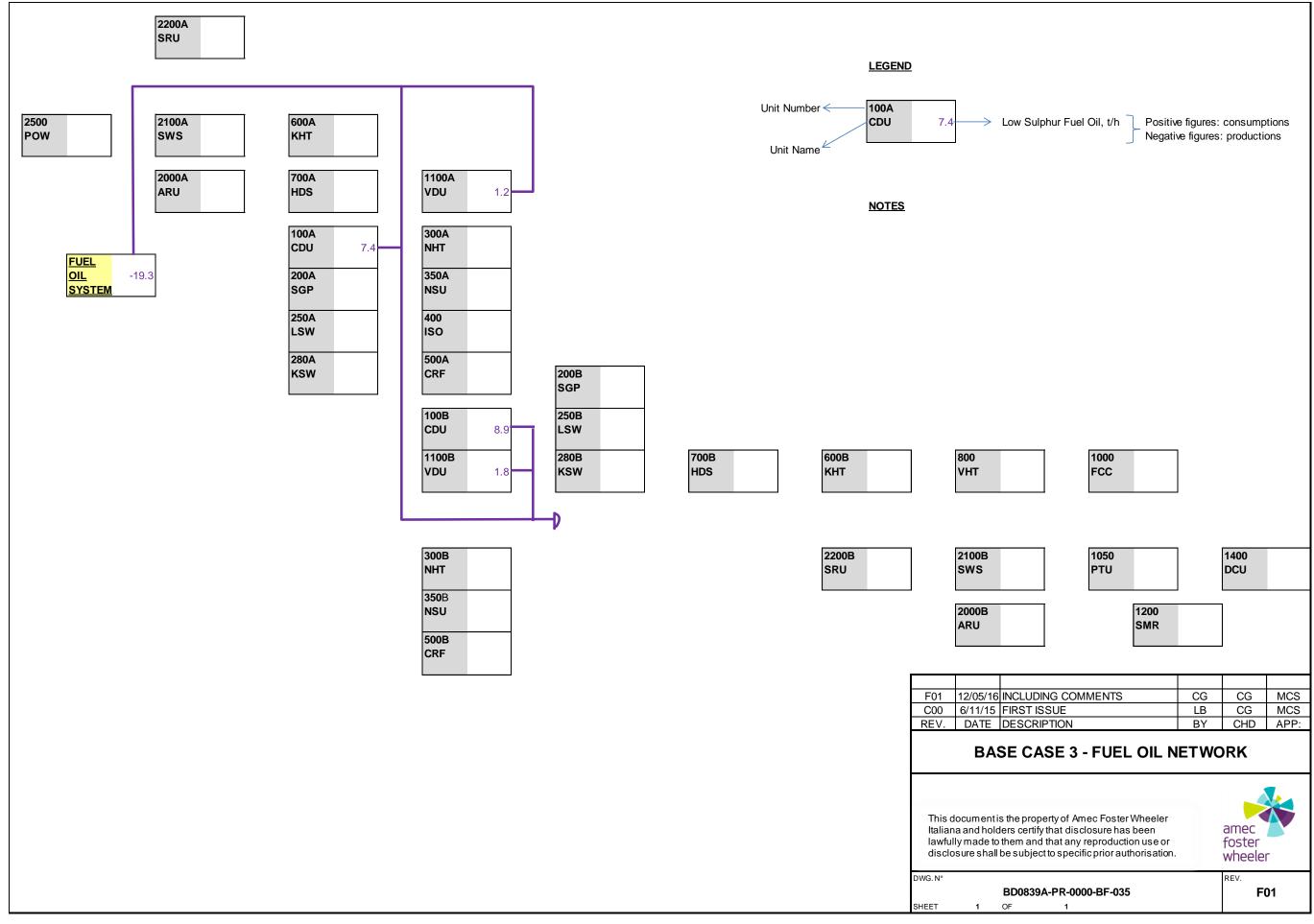


Figure 7-7: Base Case 3) Fuel oil network



## 7.4 Configuration of Power Plant

As already mentioned, Base Case 3 is considered a step-up evolution of Base Case 1: therefore, the power plant configuration nucleus of Base Case 1 (3 x 115 t/h Gas Boiler and 2 x 20 MW Steam Turbines) is kept also in Base Case 3.

In terms of power and steam demand, Base Case 3 differs from Base Case 2 only for the higher power requirement while the steam demand is nearly the same.

For Base Case 3 design, steam and power requirements are summarized in Table 7-6.

In addition to the Base Case 1 configuration (3 boilers and 2 Steam Turbine) power plant configuration for Base Case 3 is based on the addition of a Gas Turbine and an associated Heat Recovery Steam Generator (HRSG), equipped with supplementary firing.

Part of the power is produced by the Gas Turbine 38.3 MW frame, whose exhaust pass through a heat recovery steam generator generating superheated high pressure steam at the conditions required from the refinery. Natural gas only is fed to the Gas Turbine, while refinery fuel gas is fed to HRSG.

The post firing installed in the HRSG is operated at the 84% of its nominal load in order to meet the total steam requirement. In case of need, post firing load can be raised to 100% and the steam generation increased accordingly. As a matter of fact, in order to meet the HP/MP/LP steam and power requirements, it is necessary to produce an additional amount of steam with respect to what generated in the gas boilers, kept in operation as per Base Case 1.

Therefore, the HP steam generated from the HRSG is mixed with steam generated by boilers and then partially routed to the refinery users and partially sent to the Steam Turbines for power and MP/LP Steam generation. MP and LP Steam are produced through two different extraction stages at the pressure required by the users. Desuperheaters are installed both on MP and LP steam lines to bring the steam temperatures down to the values required by the refinery at power plant battery limits. Steam turbines are condensing type: exhaust steam from the steam turbines is condensed in a cooling water condenser, which operates under vacuum, and pumped, together with a demi water make up, to deaerators for BFW generation.

Also in Base Case 3 the power plant has been designed to be normally operated in balance with the grid and the refinery and such that no import/export of steam is required in normal operation. Also in this case, steam demand has higher priority over electricity demand, since refinery electrical demand can be provided by HV grid connection back-up.

A simplified scheme of power plant configuration in Base Case 3 is shown in Figure 7-8.

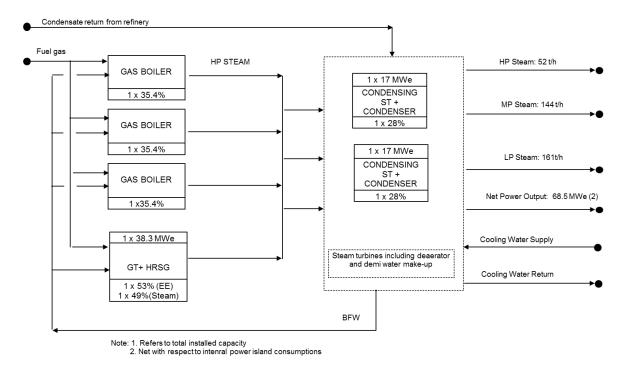
Base Case 3 power plant major equipment number and sizes are summarized hereinafter:

- 1 x 38.3 MWe Gas Turbine normally operating at 100% of the design load and 84% post fired plus 1 x HRSG producing 148.3 t/h HP Steam;
- > 3 x 115 t/h normally operating at 66% of their design load (corresponding to 75.3 t/h HP Steam)
- 2 x 20 MWe Condensing Steam Turbines normally operating at 85% of their design load (corresponding to 17 MWe each)

Either in case a steam turbine or the gas turbine trips, it is necessary to import electrical power from the national grid or, as an alternative, to put in place a load shedding plan.



#### BASE CASE 3



#### Figure 7-8: Base Case 3) Power Plant simplified Block Flow Diagram

Total installed spare capacity is summarized hereinafter:

- Gas Boilers + HRSG (Steam) +55%
- Steam Turbines + Gas Turbines (Electric Energy) +10%

The decision to expand the power plant of Base Case 1 by adding a gas turbine results in a final configuration which is different from the scheme proposed for Base Case 2; this is considered interesting for the purposes of the study, but on the other hand the discrete commercial sizes of the GT result in a lower spare capacity for the power generation. This limited margin is however deemed sufficient for a stable operation because a permanent connection to the electrical grid is typically present in European plants.



# 8. Base Case 4

### High Conversion Refinery - 350,000 BPSD Crude Capacity

The High Conversion Refinery consists of two parallel crude distillation trains (Crude Atmospheric and Vacuum Distillation Units), followed by gasoline blocks for octane improvement, kerosene sweetening units, hydrotreating units for the middle-distillates.

Two different types of Vacuum Gasoil (VGO) conversion units are also included: i.e. the Fluid Catalytic Cracking (FCC) and the High Pressure Hydrocracking (HCK). These two units have the same design capacity of 60,000 BPSD each.

Upstream of the FCC, a Vacuum Gasoil Hydrotreating (VHT) unit is present to decrease the sulphur content of FCC feedstock, in order to respect  $SO_x$  limits at FCC stack.

For Vacuum Residue conversion, a Solvent Deasphalting Unit (SDA) followed by a Coker Unit (DCU) are considered. Solvent Deasphalting allows recovering from the Vacuum Residue the paraffinic material (DAO), which can be then fed to the VGO cracking units (essentially to HCK) for being converted into more valuable distillates.

The pitch from SDA is then sent to DCU. It is considered to sell the fuel grade coke produced in DCU.

The FCC and Coker distillates are sent to finishing units to comply with the 10 ppm wt. sulphur specification for the automotive fuels.

Two parallel Steam Methane Reformer (SMR) trains are foreseen to satisfy the hydrogen demand of this complex refinery.

Base Case 4 is conceived as representative of top-class refineries, which have achieved their final configuration and capacity in a more straight-forward way with respect of Base Case 2 and 3.

This results in a more organic layout, design with parallel symmetrical trains for process and utility units and a more efficient power plant.

### 8.1 Refinery Balances

The balances developed for Base Case 4 are reported in the following tables and figures:

- Table 8-1: Base Case 4) Overall material balance
- Table 8-2: Base Case 4) Process units operating and design capacity
- Table 8-3: Base Case 4) Gasoline qualities



- Table 8-4: Base Case 4) Distillate qualities
- Table 8-5: Base Case 4) Fuel oil and bitumen qualities
- Figure 8-1: Base Case 4) Block flow diagrams with main material streams
- ▶ Table 8-6: Base Case 4) Main utility balance, fuel mix composition, CO₂ emissions

High C	ReCAP Project Preliminary Refinery Balances BASE CASE 4 Conversion Refinery, 350,000 BPSD	amec foster wheeler
PRODUCTS	Annua	al Production, kt/y
LPG		837.3
Propylene		197.1
Petrochemical Naphtha		157.3
Gasoline U95 Europe		2988.2
Gasoline U92 USA Export		1280.7
Jet fuel		2100.0
Road Diesel		6452.6
Marine Diesel		860.4
Heating Oil		1290.5
Low Sulphur Fuel Oil		0.0
Medium Sulphur Fuel Oil		0.0
High Sulphur Fuel Oil		0.0
Bitumen		0.0
Coke Fuel Grade		824.7
Sulphur		160.2
Salpha	Subtotal	
	Subtotal	17149.0
RAW MATERIALS	Con	sumptions, kt/y
Ekofisk		2870.5
Bonny Light		3738.6
Arabian Light		1614.8
Urals Medium		6196.6
Arabian Heavy		1614.8
Maya Blend (1)		645.9
Imported Vacuum Gasoil		862.4
MTBE		0.0
Natural Gas		375.8
Biodiesel		404.0
Ethanol		156.9
	Subtotal	18480.3
		kt/u
		kt/y

### Notes

1) Maya Blend consists of 50% wt. Maya crude oil + 50% wt. Arabian Light Crude Oil

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## ReCAP Project Preliminary Refinery Balances



## BASE CASE 4 High Conversion Refinery, 350,000 BPSD

## PROCESS UNITS OPERATING AND DESIGN CAPACITY

UNIT	Unit of measure	Design Capacity	Operating Capacity	Average Utilization
Crude Distillation Unit	BPSD	350000 (1)	350000	100%
Vacuum Distillation Unit	BPSD	130000 (1)	124111	95%
Naphtha Hydrotreater	BPSD	80000 (1)	76154	95%
Light Naphtha Isomerization	BPSD	23000	23000	100%
Heavy Naphtha Catalytic Reforming	BPSD	60000 (1)	58635	98%
Kero Sweetening	BPSD	24000 (1)	24000	100%
Kerosene Hydrotreater	BPSD	30000	30000	100%
Diesel Hydrotreater	BPSD	85000 (1)	78570	92%
Heavy Gasoil Hydrotreater	BPSD	36000	31615	88%
Fluid Catalytic Cracking	BPSD	60000	60000	100%
FCC Gasoline Hydrotreater	BPSD	24000	23128	96%
Hydrocracker	BPSD	60000	57000	95%
Solvent Deasphalting	BPSD	30000	27727	92%
Delayed Coker	BPSD	50000	46000	92%
Sulphur Recovery Unit	t/d Sulphur	750 (1)	458	61%
Steam Reformer	Nm ³ /h Hydrogen	130000 (1)	114653	88%

#### Notes

1) Multiple units in parallel to be considered.

	V.5 /2016 H	RECAP FIDIECT			amec foster wheeler	
EXCESS NAPI	ТНА	GAS	SOLINE QUALI	<u>TIES</u>		
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
NAH	HT HEAVY NAPHTHA		36,942.44	23.485%	49,520.70	22.197%
NAL	HT LIGHT NAPHTHA		104,554.84	66.467%	150,006.95	67.238%
LRF	LIGHT REFORMATE		31.15	0.020%	44.00	0.020%
HLN	LIGHT NAPHTHA ex HO	CU	15,775.79		23,528.39	10.546%
		Total	157,304.22	100.000%	223,100.04	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3		VL	705.08		725.00
	22110111,110/110		•=			
SPM VPR	SULFUR, PPMW VAPOR PRESSURE, K	(PA	WT VL	56.57 69.00		500.00 69.00
SPM	SULFUR, PPMW VAPOR PRESSURE, K	(PA	WT			
SPM VPR	SULFUR, PPMW VAPOR PRESSURE, K	(PA	WT	69.00	Volume Quantity	
SPM VPR Unl. Premium Component BU#	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG	(PA	WT VL Weight Quantity 20,294.41	69.00 Weight Percent 0.679%	Quantity 34,843.25	69.00
SPM VPR Unl. Premium Component BU# R10	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100	(PA	WT VL Weight Quantity 20,294.41 1,452,479.89	69.00 Weight Percent 0.679% 48.607%	Quantity 34,843.25 1,752,086.72	69.00 Volume Percent 0.883% 44.388%
SPM VPR Unl. Premium Component BU# R10 ISO	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE		WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28	69.00 Weight Percent 0.679% 48.607% 18.415%	Quantity 34,843.25 1,752,086.72 832,505.72	69.00 Volume Percent 0.883% 44.388% 21.091%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA		WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34	69.00 Weight Percent 0.679% 48.607% 18.415% 27.048%	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638%
SPM VPR Unl. Premium Component BU# R10 ISO	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE	treated	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04	69.00 Weight Percent 0.679% 48.607% 18.415% 27.048% 5.251%	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA		WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34	69.00 Weight Percent 0.679% 48.607% 18.415% 27.048%	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638%
SPM VPR Unl. Premium Component BU# R10 ISO LCN	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA	treated	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04	69.00 Weight Percent 0.679% 48.607% 18.415% 27.048% 5.251%	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000%
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA	treated	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97	69.00 Weight Percent 0.679% 48.607% 18.415% 27.048% 5.251% 100.000%	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH Quality RHO SPM VPR	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH Quality RHO SPM VPR BEN	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min 720.00	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V D86 @ 150°C, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37           90.23	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37           90.23           5.00	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min 720.00	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00 15.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY OLE	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL VL VL VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37           90.23           5.00           11.79	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min 720.00	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00 15.00 18.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY OLE EOH	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V OLEFINS, %V ETHANOL, VOI%	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL VL VL VL VL VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37           90.23           5.00           11.79           5.00	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min 720.00 75.00	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00
SPM VPR Unl. Premium Component BU# R10 ISO LCN EOH EOH RHO SPM VPR BEN ARO E50 OXY OLE	SULFUR, PPMW VAPOR PRESSURE, K (95) EU C4 TO MOGAS/LPG REFORMATE 100 ISOMERATE FCC LIGHT NAPHTHA ETHANOL DENSITY, KG/M3 SULFUR, PPMW VAPOR PRESSURE, K BENZENE, %V AROMATICS, %V D86 @ 150°C, %V OXYGENATES, %V	treated Total	WT VL Weight Quantity 20,294.41 1,452,479.89 550,286.28 808,236.34 156,901.04 2,988,197.97 Blending Basis VL WT VL VL VL VL VL VL VL VL	69.00           Weight Percent           0.679%           48.607%           18.415%           27.048%           5.251%           100.000%           Value           757.04           2.74           60.00           0.76           33.37           90.23           5.00           11.79	Quantity 34,843.25 1,752,086.72 832,505.72 1,130,400.47 197,359.80 3,947,195.96 Min 720.00	69.00 Volume Percent 0.883% 44.388% 21.091% 28.638% 5.000% 100.000% Max 775.00 10.00 60.00 1.00 35.00 15.00 18.00

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REV 12/05, Unl. Premium	/2016	High Conver	ReCAP Project inary Refinery B BASE CASE 4 rsion Refinery, 3	alances 50,000 BPSD	fo	mec oster heeler
Component	(02)		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
BU#	C4 TO M	OGAS/LPG	19,590.39	1.530%	33,634.51	1.971%
HRF	HEAVY I	REFORMATE	318.85	0.025%	376.45	0.022%
R10	REFORM	1ATE 100	720,137.36	56.232%	868,681.97	50.894%
ISO	ISOMER	ATE	304,310.62	23.762%	460,379.15	26.973%
LCN	FCC LIG	HT NAPHTHA treated	93,180.17	7.276%	130,321.92	7.635%
HLN	LIGHT N/	APHTHA ex HCU	143,118.89	11.175%	213,450.99	12.506%
		Total	1,280,656.27	100.000%	1,706,844.99	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSITY	′, KG/M3	VL	750.31	720.00	775.00
SPM	SULFUR	, PPMW	WT	1.36		10.00
VPR		PRESSURE, KPA	VL	60.00		60.00
BEN	BENZEN	E, %V	VL	0.96		1.00
ARO	AROMA	TICS, %V	VL	35.00		35.00
E50	D86 @ 1	50°C, %V	VL	88.80	75.00	
OXY	OXYGEN	IATES, %V	VL	0.00		15.00
OLE	OLEFINS		VL	3.73		18.00
EOH	ETHANO		VL	0.00		10.00
DON	Research	,	VL	92.00	92.00	
RON	Researci		VL	52.00	52.00	

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<b>REV</b> 12/05/1	2016 Prelim	ReCAP Project inary Refinery B BASE CASE 4 rsion Refinery, 3	alances	f	amec oster vheeler
LPG PRODUCT		ILLATE QUAL	ITIES		
Component		Weight Quantity	Weight Percent	Volume	Volume Percent
•				Quantity	
LG#	LPG POOL Total	931,068.08 931,068.08	100.000% 100.000%	<u>1,656,084.90</u> 1,656,084.90	100.000% 100.000%
Quality		Blending Basis	Value	Min	Max
SPM	SULFUR, PPMW	WT	5.00		140.00
VPR	VAPOR PRESSURE, KPA	VL	698.51	632.40	887.60
OLW Jet Fuel EU	OLEFINS, %W	WT	2.56		30.00
Component		Weight Quantity	Weight Percent	Volume	Volume Percent
KED	HT KERO	1,032,814.13	49.182%	Quantity 1,301,593.11	49.357%
KED KMCR4	KERO FROM MEROX URALS	790,801.35	37.657%	989,738.86	37.532%
KMCR5	KERO FROM MEROX AR.HVY	192,157.99	9.150%	240,197.48	
KMCR6	KERO FROM MEROX MAYA	84,226.53		105,547.03	
	Total		100.000%	2,637,076.49	100.000%
Quality		Blending Basis	Value	Min	Мах
RHO	DENSITY, KG/M3	VL	796.34	775.00	840.00
SUL	SULFUR, %W	WT	0.11		0.30
FLC Diesel EU	FLASH POINT, °C (PM, D93)	VL	40.00	38.00	<u> </u>
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
LCO	LIGHT CYCLE OIL treated	568,379.17	8.808%	598,293.86	7.819%
HCN	FCC HEAVY NAPHTHA	450,708.26	6.985%	530,245.01	6.929%
KED	HT KERO	282,659.01	4.381%	356,218.03	4.655%
DLG	DESULF LGO	2,542,546.59	39.403%	3,016,069.50	
HKR	KERO ex HCU	716,644.14	11.106%	903,143.22	11.802%
HLG	DESULF LGO ex HCU	1,487,657.54		1,789,125.12	23.380%
FAM	BIODIESEL	404,037.66 6,452,632.37	6.262% 100.000%	459,133.71 7,652,228.45	
Quality		Blending Basis	Value	Min	Мах
-		-			
RHO	DENSITY, KG/M3	VL WT	843.24	820.00	845.00
SPM	SULFUR, PPMW		8.05	FF 00	10.00
FLC	FLASH POINT, °C (PM, D93)	VL	59.17	55.00	
	CETANE INDEX D4737	VL	46.16	46.00	
V04	VISCOSITY @ 40°C, CST	WT	2.53	2.00	
E36	D86 @360°C, %V	VL VL	98.23	95.00	
FAM	BIODIESEL CONTENT, %VOL		6.00	6.00	7.00

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	REV.5ReCAP Project12/05/2016Preliminary Refinery Balances					mec
		50,000 BPSD		oster vheeler		
Heating Oil		DIST	ILLATE QUAL	<u>ITIES</u>		
Component			Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
KSCR1	SR KER	O EKOFISK	206,736.19	16.020%	258,097.61	17.006%
LGCR2	LGO BO		552,293.87	42.796%	634,091.70	41.779%
LGCR1	LGO EK		523,288.62	40.548%	616,358.80	40.611%
LVCR4	LVGO U		8,207.79		9,164.57	0.604%
	•	Total	1,290,526.47	100.000%	1,517,712.69	100.000%
Quality			Blending Basis	Value	Min	Max
RHO	DENSIT	Y, KG/M3	VL	850.31	815.00	860.00
SPM		R, PPMW	WT	1,000.00		1,000.00
FLC	FLASH I	POINT, °C (PM, D93)	VL	63.80	55.00	
CIN		INDEX D4737	VL	48.30	40.00	
V04	VISCOS	ITY @ 40°C, CST	WT	2.81	2.00	6.00
MARINE DIES	EL				Volume	
-	EL		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
Component KSCR1		O EKOFISK	Weight Quantity 181,790.34	Weight Percent 21.130%		
Component KSCR1				_	Quantity	22.489%
Component KSCR1 LGCR2	SR KER		181,790.34	21.130%	Quantity 226,954.23	22.489% 63.320%
Component KSCR1 LGCR2 VLG	SR KER	NNY FLGO ex VHT	181,790.34 556,585.57	21.130% 64.693% 12.205%	Quantity 226,954.23 639,019.02	22.489% 63.320% 12.313%
MARINE DIES Component KSCR1 LGCR2 VLG LVCR4	SR KER LGO BO DESULF	NNY FLGO ex VHT	181,790.34 556,585.57 105,003.52	21.130% 64.693% 12.205%	Quantity 226,954.23 639,019.02 124,264.52	22.489% 63.320% 12.313% 1.878%
Component KSCR1 LGCR2 VLG	SR KER LGO BO DESULF	NNY LGO ex VHT RALS	181,790.34 556,585.57 105,003.52 16,971.55	21.130% 64.693% 12.205% 1.973%	Quantity 226,954.23 639,019.02 124,264.52 18,949.93	22.489% 63.320% 12.313% 1.878%
Component KSCR1 LGCR2 VLG LVCR4 Quality	SR KER LGO BO DESULF LVGO U	NNY LGO ex VHT RALS	181,790.34 556,585.57 105,003.52 16,971.55 860,350.98	21.130% 64.693% 12.205% 1.973% 100.000%	Quantity 226,954.23 639,019.02 124,264.52 18,949.93 1,009,187.70	22.489% 63.320% 12.313% 1.878% 100.000% Max
Component KSCR1 LGCR2 VLG LVCR4 Quality RHO SPM	SR KER LGO BO DESULF LVGO U	NNY LGO ex VHT RALS Total	181,790.34           556,585.57           105,003.52           16,971.55           860,350.98           Blending Basis           VL           WT	21.130% 64.693% 12.205% 1.973% 100.000% Value	Quantity 226,954.23 639,019.02 124,264.52 18,949.93 1,009,187.70	22.489% 63.320% 12.313% 1.878% 100.000% Max 890.00
Component KSCR1 LGCR2 VLG LVCR4 Quality RHO SPM	SR KER LGO BO DESULF LVGO U DENSIT	NNY LGO ex VHT RALS Total Y, KG/M3	181,790.34 556,585.57 105,003.52 16,971.55 860,350.98 Blending Basis VL	21.130% 64.693% 12.205% 1.973% 100.000% Value 852.52	Quantity 226,954.23 639,019.02 124,264.52 18,949.93 1,009,187.70	22.489% 63.320% 12.313% 1.878% 100.000% Max 890.00
Component KSCR1 LGCR2 VLG LVCR4 Quality RHO SPM FLC	SR KER LGO BO DESULF LVGO U DENSIT SULFUR FLASH I	NNY LGO ex VHT RALS Total Y, KG/M3 R, PPMW	181,790.34           556,585.57           105,003.52           16,971.55           860,350.98           Blending Basis           VL           WT	21.130% 64.693% 12.205% 1.973% 100.000% Value 852.52 1,000.00	Quantity 226,954.23 639,019.02 124,264.52 18,949.93 1,009,187.70 Min	22.489% 63.320% 12.313% 1.878% 100.000% Max 890.00
Component KSCR1 LGCR2 VLG LVCR4	SR KER LGO BO DESULF LVGO U DENSIT SULFUR FLASH I CETANE	NNY LGO ex VHT RALS Total Y, KG/M3 R, PPMW POINT, °C (PM, D93)	181,790.34           556,585.57           105,003.52           16,971.55           860,350.98           Blending Basis           VL           WT           VL	21.130% 64.693% 12.205% 1.973% 100.000% Value 852.52 1,000.00 60.00	Quantity 226,954.23 639,019.02 124,264.52 18,949.93 1,009,187.70 Min 60.00	100.000%

REV 12/05/ Low Sulphur F	/2016 Preli High Conv <u>FUEL (</u>	ReCAP Project minary Refinery B BASE CASE 4 rersion Refinery, 3 DIL / BITUMEN Q	alances 350,000 BPSD	f	amec oster vheeler
Component		Weight Quantity	Weight Percent	Volume Quantity	Volume Percent
SLU	FCC SLURRY OIL	231,363.57	89.661%	243,540.60	89.721%
HHR	RESIDUE ex HCU	6,809.62	2.639%	8,073.05	2.974%
VDCR4	VDU RES MIX4	19,868.83	7.700%	19,829.17	7.305%
	Tot	al 258,042.02	100.000%	271,442.83	100.000%
Quality		Blending Basis	Value	Min	Max
RHO	DENSITY, KG/M3	VL	950.63		991.00
SUL	SULFUR, %W	WT	0.50		0.50
FLC	FLASH POINT, °C (PM, D93)	VL	197.68	66.00	
V05	VISCOSITY @ 50°C, CST	WT	131.16		380.00
CCR	CONRADSON CARBON RES, %	V WT	1.16		15.00

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<b>REV.6</b> 19/04/2017	Hig	Preliminar B	CAP Project y Refinery Ba ASE CASE 4 n Refinery, 3			ame fost whe	
		MAIN U	TILITY BALA	NCE			
	FUEL	POWER	_	MP STEAM	LP STEAM	COOLING WATER (2)	RAW WATER
	Gcal/h	kW	tons/h	tons/h	tons/h	m3/h	m3/h
MAIN PROCESS UNITS	975	83180	-20	160	174	35364	
BASE LOAD	440	30000	20	40	40		
	419	-119235	0	-200	-214	40000	
SEA WATER SYSTEM		1712				-10000	
COOLING TOWER SYSTEM		4342				-25364	
TOTAL	1393	0	0	0	0	0	2900
LOW SULPHUR FUEL OIL (3) FCC COKE NATURAL GAS to fuel system NATURAL GAS to gas turbine TOTAL	30.7 14.5 0.1 22.9 125.4	258.0 121.7 1.1 192.2 1053.1	25% 12% 0% 18%				
		<u>C02</u>	2 EMISSIONS	<u>5</u>			
	t/h						
From Steam Reformer feed (4)	91.6						
From FG/NG combustion	217.8						
From FO combustion	98.3						
From FCC coke combustion	53.1						
TOTAL	460.8	correspond	ding to	3871.0 232.1	kt⁄y kg CO2 / t cr	ude	
<b>Notes</b> 1) (-) indicates productions 2) 10°C temperature increase h 3) LSFO is burnt in CDU and VI 4) Composed of Natural Gas pli	DU heaters	idered					

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**REV.5** 12/05/2016

**ReCAP Project** 

**Overall Refinery Balance** 

BASE CASE 4

High Conversion Refinery, 350,000 BPSD

## **BLOCK FLOW DIAGRAM**

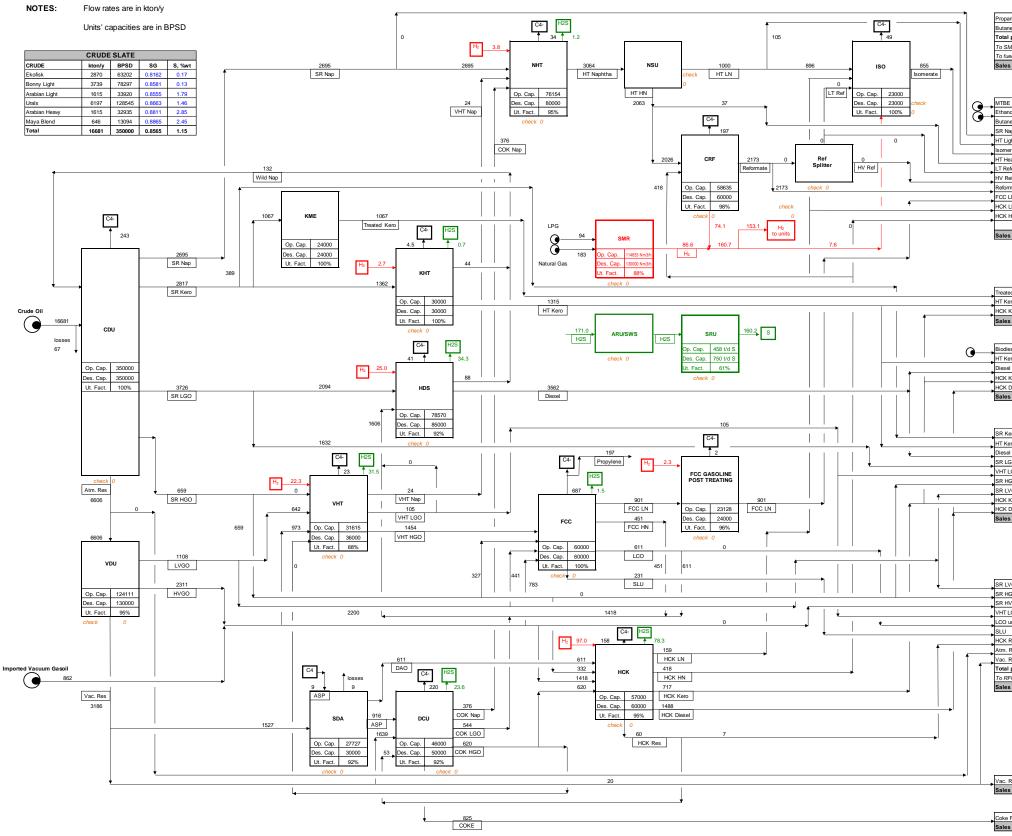


Figure 8-1: Base Case 4) Block flow diagrams with main material streams

Revision F02 20/04/2017

	LPG
oane	224
ane	707
al prod.	931
SMR	94
uel	0
es	837

	Propylene
Propylene	197
Sales	197

	U 95-EU	U 92-US	Excess Naph.	тот
ΒE	0	0	0	0
nanol	157	0	0	157
tanes	20	20	0	40
Naphtha	0	0	0	0
Light Naphtha	0	0	105	105
merate	550	304	0	855
Heavy Naphtha	0	0	37	37
Reformate	0	0	0	0
Reformate	0	0	0	0
formate	1452	720	0	2173
C LN	808	93	0	901
K LN	0	143	16	159
K HN	0	0	0	0
les	2988	1281	157	4426

	Jet Fuel
ated Kero	1067
Kero	1033
Kero	0
es	2100
	Diesel
diesel	404
Kero	283
sel	3562
K Kero	717
K Diesel	1488
es	6453

	Heating Oil	Mar. Dies.	TOT
Kero	207	182	389
Kero	0	0	0
sel	0	0	0
LGO	1076	557	1632
T LGO	0	105	105
HGO	0	0	0
LVGO	8	17	25
K Kero	0	0	0
K Diesel	0	0	0
les	1291	860	2151

	LSFO	MSFO	HSFO	TOT
LVGO	0	0	0	0
HGO	0	0	0	0
HVGO	0	0	0	0
T LGO	0	0	0	0
O untreated	0	0	0	0
U	231	0	0	231
K Residue	7	0	0	7
n. Residue	0	0	0	0
c. Residue	20	0	0	20
tal prod.	258	0	0	258
RFO	258		-	258
les	0	0	0	0

	Bitumen
. Res.	0
es	0
	Coke
e Fuel Grade	825
es	825

	Sulphur
Sulphur	160
Sales	160

# REV.6

19/04/2017

#### **ReCAP** Project 1-BD-0839A

### CO₂ EMISSION - PER UNIT BASE CASE 4

					PROCESS									
		UNIT	Unit of measure	Design Capacity	Operatin	g Fuel Consum	ption [t/h]	Operat	ing CO ₂ Emiss	ion [t/h]	% on Total	$CO_2$ concentr.	Operating Temperature	Notes
		UNIT	Unit of measure	Design Capacity	Fuel Gas	Fuel Oil	Coke	Fuel Gas	Fuel Oil	Coke	CO ₂ Emission	in flue gases, vol %	[°C]	(1)
0100A	CDU	Crude Distillation Unit	BPSD	175000	-	13.0	-	-	41.6	-	9.0%	11.3%	200 ÷ 220	(2)
0100B	CDU	Crude Distillation Unit	BPSD	175000	-	13.0	-	-	41.6	-	9.0%	11.3%	200 ÷ 220	(2)
0300A	NHT	Naphtha Hydrotreater	BPSD	40000	0.5	-	-	1.4	-	-	0.3%	8.1%	420 ÷ 450	(2)
0350A	NSU	Naphtha Splitter Unit	BPSD	40000	0.6	-	-	1.6	-	-	0.4%	8.1%	420 - 430	(3)
0300B	NHT	Naphtha Hydrotreater	BPSD	40000	0.5	-	-	1.4	-	-	0.3%	8.1%	420 ÷ 450	(3)
0350B	NSU	Naphtha Splitter Unit	BPSD	40000	0.6	-	-	1.6	-	-	0.4%	8.1%	420 - 430	(3)
0500A	CRF	Catalytic Reforming	BPSD	30000	6.6	-	-	18.2	-	-	3.9%	8.1%	180 ÷ 190	
0500B	CRF	Catalytic Reforming	BPSD	30000	6.6	-	-	18.2	-	-	3.9%	8.1%	180 ÷ 190	
0600A	KHT	Kero HDS	BPSD	15000	0.2	-	-	0.6	-	-	0.1%	8.1%	420 ÷ 450	
0600B	KHT	Kero HDS	BPSD	15000	0.2	-	-	0.6	-	-	0.1%	8.1%	420 ÷ 450	
0700A	HDS	Gasoil HDS	BPSD	42500	1.7	-	-	4.6	-	-	1.0%	8.1%	200 ÷ 220	
0700B	HDS	Gasoil HDS	BPSD	42500	1.7	-	-	4.6	-	-	1.0%	8.1%	200 ÷ 220	
0800	VHT	Vacuum Gasoil Hydrotreater	BPSD	36000	1.9	-	-	5.3	-	-	1.2%	8.1%	200 ÷ 220	
0900	HCK	Vacuum Gasoil Hydrocracker	BPSD	60000	6.2	-	-	16.9	-	-	3.7%	8.1%	200 ÷ 220	
1000	FCC	Fluid Catalytic Cracking	BPSD	60000	-	-	14.5	-	-	53.1	11.5%	16.6%	300 ÷ 320	
1100A	VDU	Vacuum Distillation Unit	BPSD	65000	-	2.4	-	-	7.6	-	1.6%	11.3%	200 ÷ 220	(2)
1100B	VDU	Vacuum Distillation Unit	BPSD	65000	-	2.4	-	-	7.6	-	1.6%	11.3%	200 ÷ 220	(2)
10004	SMR	Steam Reformer	Nm ³ /h Hydrogen	05000	3.6	-	-	9.9	-	-	2.1%	8.1%	405 - 400	(4)
1200A	SIVIR	Steam Reformer Feed	Nm ² /n Hydrogen	85000	10.9 (5)	-	-	45.8	-	-	9.9%	24.2%	135 ÷ 160	(4)
1200B	SMR	Steam Reformer	Nm ³ /b Lh dromon	85000	3.6	-	-	9.9	-	-	2.1%	8.1%	105 - 100	(4)
1200B	SIVIK	Steam Reformer Feed		Hydrogen 85000		-	-	45.8	-	-	9.9%	24.2%	135 ÷ 160	(4)
1300	SDA	Solvent Deasphalting	BPSD	35000	3.3	-	-	9.1	-	-	2.0%	8.1%		
1400	DCU	Delayed Coking	BPSD	46000	6.0	-	-	16.3	-	-	3.5%	8.1%	200 ÷ 220	
						Sub Tota	I Process Units		363.1		78.8%			

					AUXILIAR	UNITS								
2200	SRU	Sulphur Recovery & Tail Gas Treatment	t/d Sulphur	3 x 250	0.06	-	-	0.16	-	-	0.0%	< 8%	380 ÷ 400	
	Sub Total Auxiliary Units 0.16 0.0%													

	POWER UNITS													
2500	POW	Power Plant - Gas Turbine	kW	175000	22.9	-	-	60.8	-	-	13.2%	3.2%	115 ÷ 140	
2000	1.000	Power Plant - HRSG + Steam Boilers		173000	13.4	-	-	36.7	-	-	8.0%	8.1%	115 ÷ 140	
Sub Total Power Units 97.6 21.2%														
							-							
TOTAL CO ₂ EMISSION 460.8 100%														
								54%	21%	12%				

#### Notes

(1) Fuel gas is a mixture of refinery fuel gas (99.8%) and imported natural gas (0.2%).

(2) Both in train A and B, Crude and Vacuum Distillation heaters (units 0100A/1100A and 0100B/1100B) have a common stack.

(3) Both in train A and B, Naphtha Hydrotreater and Naphtha Splitter heaters (units 0300A/0350A and 0300B/0350B) have a common stack.

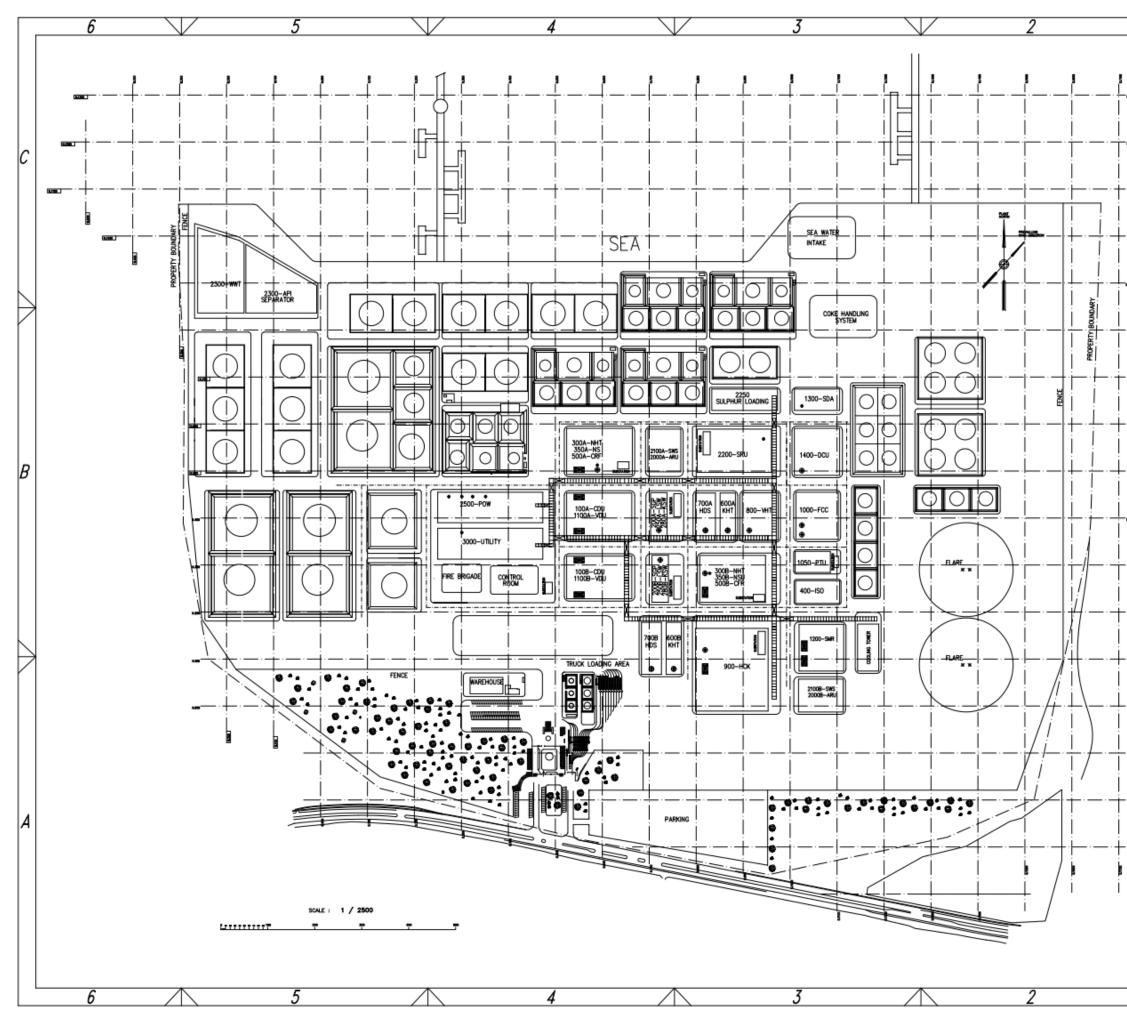
(4) Natural gas and LPG are used as feed to the Steam Reformer, units 1200A/B; after reaction and hydrogen purification, tail gas and fuel gas are burnt in the Steam Reformer furnaces. (5) Plus 5.6 t/h LPG.





# 8.2 Refinery Layout

The layout of the Base Case 4 refinery is enclosed in Figure 8-2.



		_			
		, 	1		
	<u> </u>	_	UNIT LIST		
	UN	ir I	DESCRIPTION		
		100A	CRUDE DISTILLATION (CDU)		
-		1100A	VACUUM DISTILLATION (VOU)		
		100B	CRUDE DISTILLATION (CDU)		
		11008	VACUUM DISTILLATION (VDU)		
		200A	SATURATED GAS PLANT (SGP)		
-		250A	LPG SMEETENING (LSW)		
					r
		2008	SATURATED GAS PLANT (SOP)		C
		2508	LPG SMEETENING (LSW)		
		250A	KERD SWEETENING (KSW)		
		2808	KERO SWEETENING (KSW)		
		300A	NAPHTHA HIDROTREATER (NHT)		
	UNTS	3008	NAPHTHA HYDROTREATER (NHT)		
	ROCESS	$\vdash$	NAPHTHA SPLITTER (NSU)		
	980	350A			
		400	ISOMERIZATION (ISO)		
_		3508	NAPHTHA SPLITTER (NSU)		
-		500A	CATALYTIC REFORMING (ORF)		
		5008	CATALYTIC REFORMING (ORF)		$\leftarrow$
		600A	KERO HDS (KHT)		1
		$\vdash$	KERO HDS (KHT)		
		600B			
		700A	GASOIL HDS (HDS)		
		7008	GASOIL HDS (HDS)		
		800	VACUUM GASOL HYDROTREATER (VHT)		
		900	VACUUM GASOL HYDROGRACKING (HCK)		
		1000	FLUID CATALYTIC CRACKING (FCC)		
		$\vdash$			
		1050	FCC GASOLINE POST-TREATMENT UNIT (PTU)	)	
		1200	steam reforming (smr)		
		1300	SOLVENT DEASPHALTING (SDA)		
		1400	DELAYED COKING (DCU)		R
		2000A	AMINE WASHING AND REGENERATION (ARU)		
		20008	AMINE WASHING AND RECEINERATION (ARU)		
	NITS	$\vdash$			
-	n k	2100A	SOUR WATER STRIPPER (SWS)		
	VIDULARY	21008	SOUR WATER STRIPPER (SWS)		
	2	2200	SULPHUR RECOVERY (SRU)		
			TAIL GAS TREATMENT		
		2250	SULPHUR LOADING		
	1		WASTE WATER TREATMENT (WWT)		
		2300			
			API SEPARATOR		
	ų ۴	2300 2500			
	PONER		API SEPARATOR		
	POMER		API SEPARATOR		
	POMER	2500	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\leftarrow$
	POMER	2500 3000	API SEPARATOR POWER PLANT (POW)		$\in$
	POWER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\in$
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\in$
	PONGR	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	POWER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	POMER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\leftarrow$
	POMER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	POMER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\leftarrow$
	POMER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	POWER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		$\langle$
	POWER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		A
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		A
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		A
	PONER	2500 3000	API SEPARATOR PORER PLANT (POW) UTILITY UNITS		A
		2500	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS		A
		2500 3000	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS	87 080 MP.	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS PRET REAK ADDAREDW APIENT ATLANCE	APPROVED FOR CONSTRUCTION	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS	APPROVED FOR CONSIMUCTION OWN, PEY. BATE Advanture	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS PRET REAK ADDAREDW APIENT ATLANCE	APPROVED FOR CONSTRUCTION DIVIG. REV. EARLE	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTILITY UNITS OFF SITES UNITS PRET REAK ADDAREDW APIENT ATLANCE	APPROVED HER CONSTRUCTION DWG. REV. DATE ADDACTIVE CHEAR N.	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTUITY UNITS OFF SITES UNITS OFF SITES UNITS FOSTER Wheeler	APPENDED-FOR CONSINUE-TION OVIG. REV. DATE INSURTINE ORDERIX BUSINERS	A
		2500 3000 4000	API SEPARATOR PONER PLANT (POW) UTUITY UNITS OFF SITES UNITS OFF SITES UNITS FOSTER Wheeler	APPROXECTOR         CAPE         APPROXECTOR           OVER ATT         EAR         EAR           SHET         07         EAR	4
		2500 4000 4000	API SEPARATOR POMER PLANT (POW) UTUTY UNITS OFF SITES UNITS OFF SITES UNITS FOSTER Wheeler BASE CASE 4 CONVERSION REFINERY 350,000 BPSD	Armonacing         Armonacing         Armonacing           Armonacing         Bart         Bart           Bartura         Bartura         Bartura           Casaming         Armonacing         Bartura	4
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# 8.3 Main Utility Networks

The main utility balances have been reported on block flow diagrams, reflecting the planimetric arrangement of the process units and utility blocks.

In particular, the following networks' sketches have been developed:

- Figure 8-3: Base Case 4) Electricity network
- Figure 8-4: Base Case 4) Steam networks
- Figure 8-5: Base Case 4) Cooling water network
- Figure 8-6: Base Case 4) Fuel Gas/Offgas networks
- Figure 8-7: Base Case 4) Fuel oil network

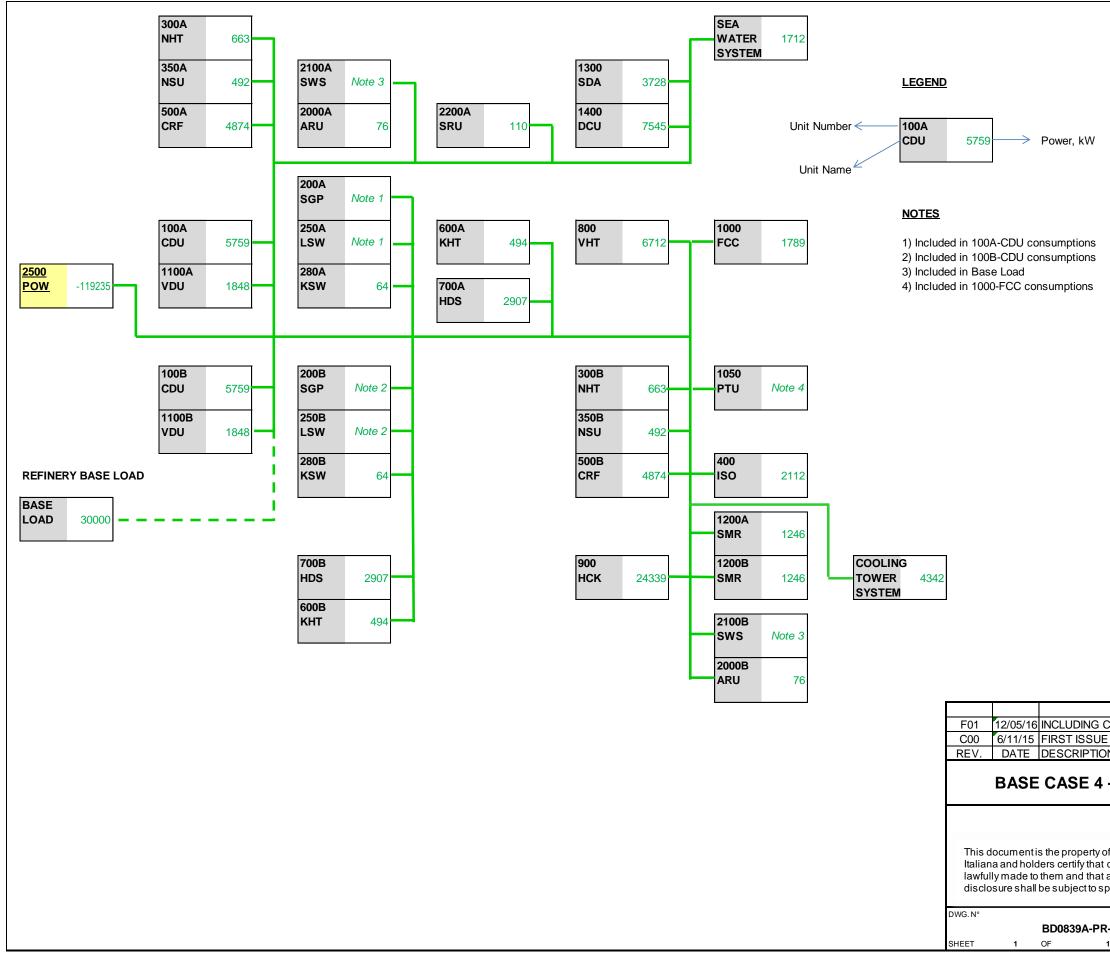


Figure 8-3: Base Case 4) Electricity network

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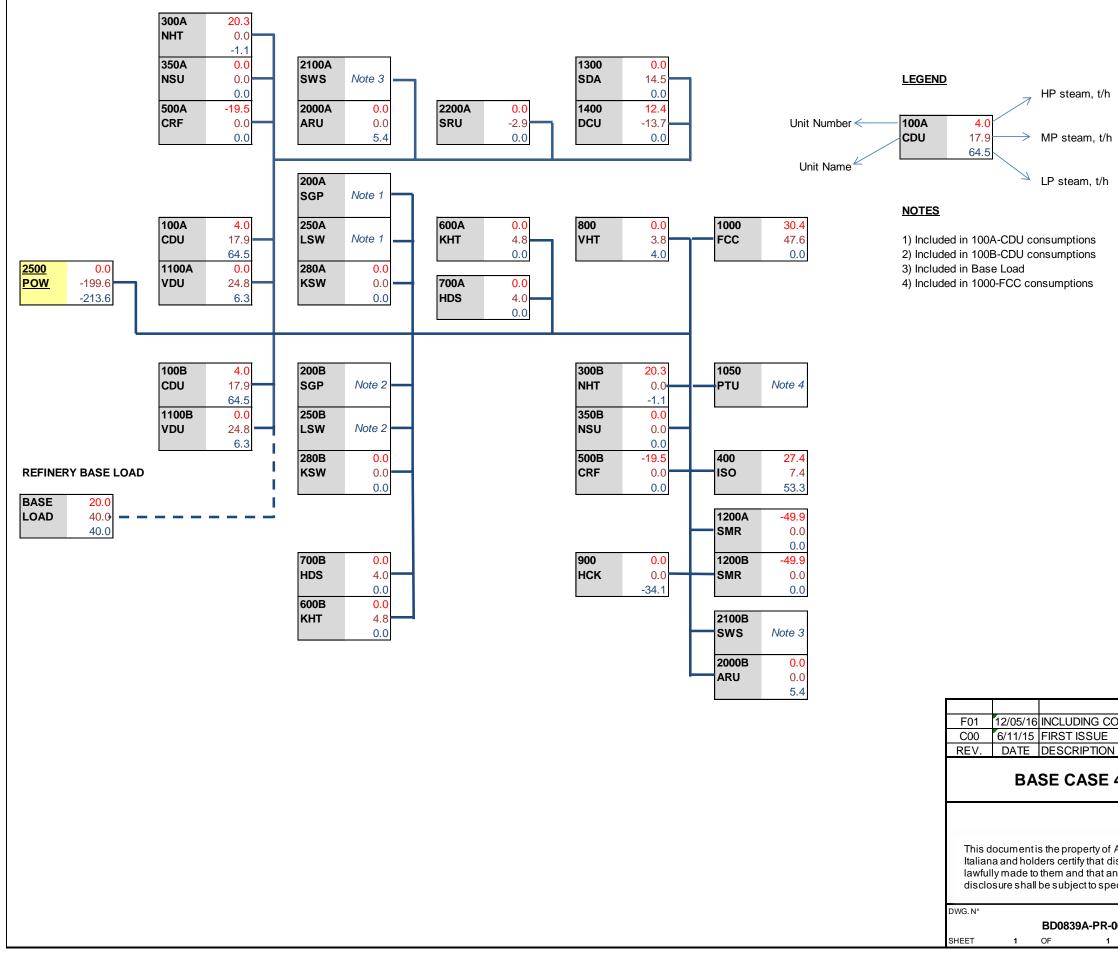


Figure 8-4: Base Case 4) Steam networks

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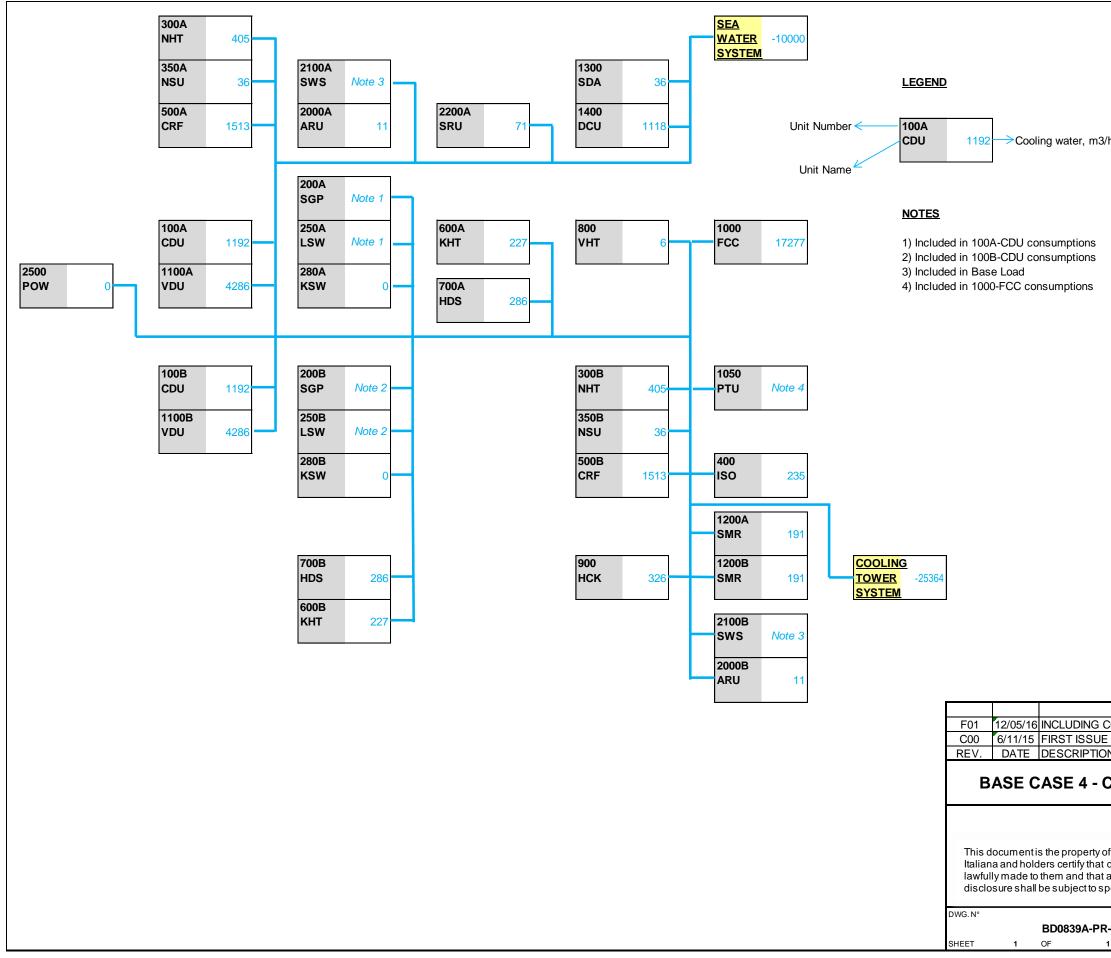


Figure 8-5: Base Case 4) Cooling water network

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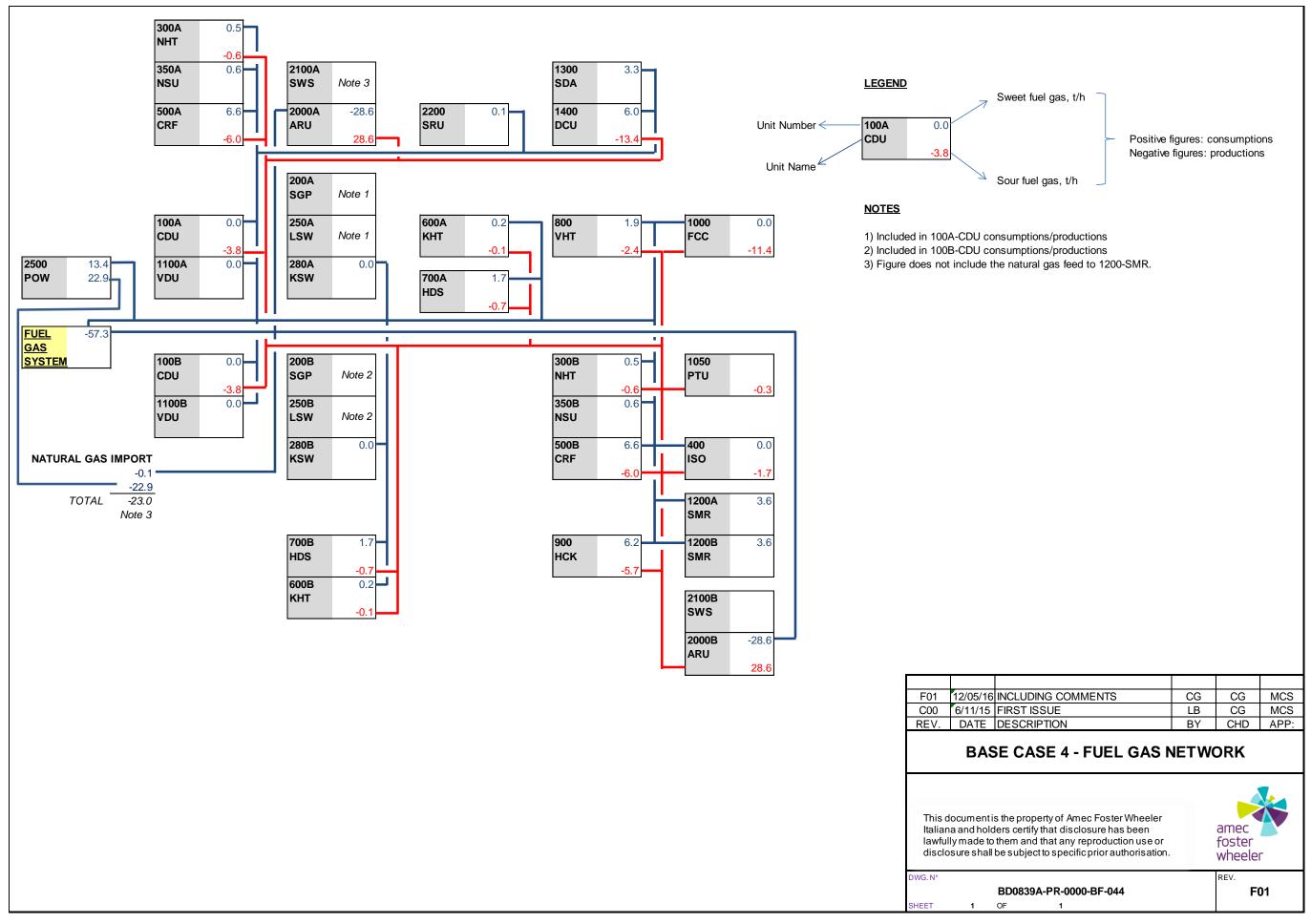


Figure 8-6: Base Case 4) Fuel Gas/Offgas networks

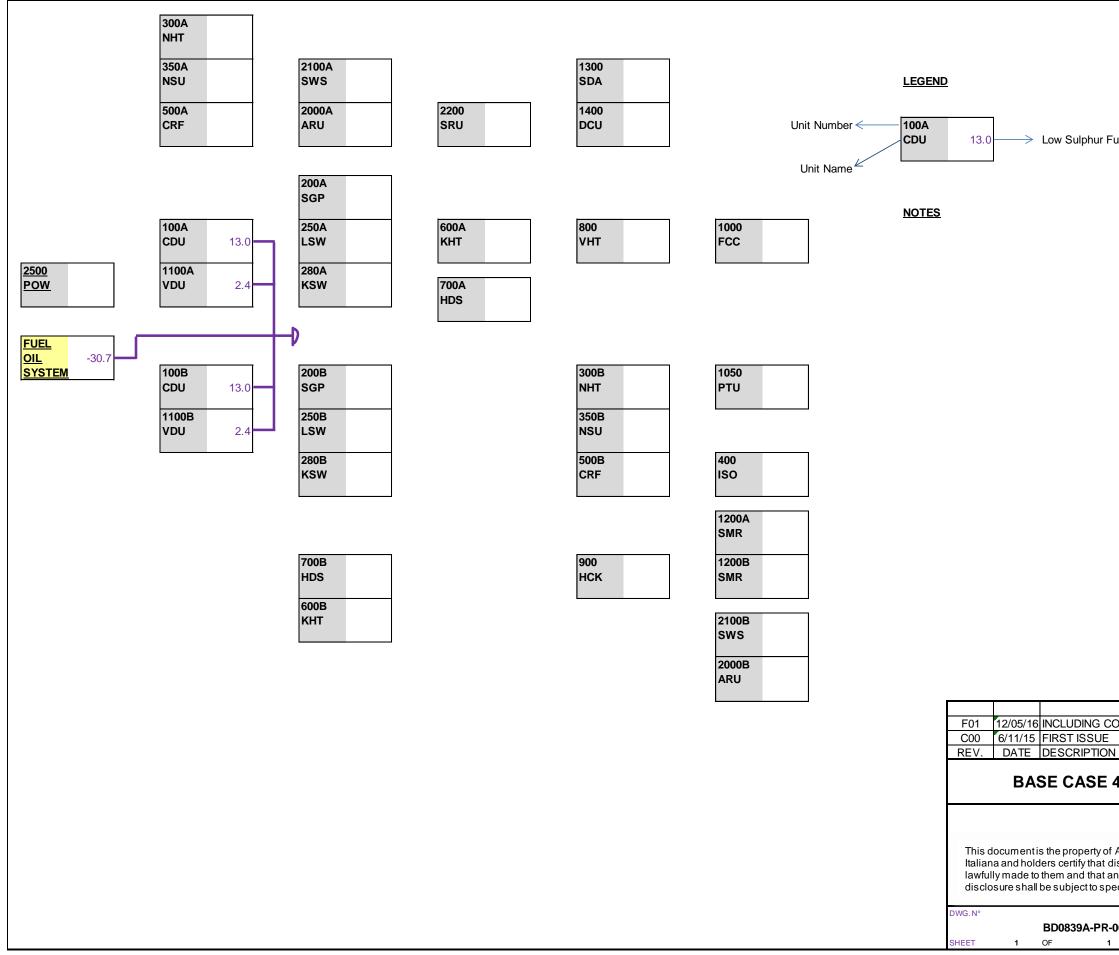


Figure 8-7: Base Case 4) Fuel oil network

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## 8.4 Configuration of Power Plant

Base Case 4, representing a high capacity, high conversion refinery, is not considered as an evolution of a different scheme.

Following the same approach, also it has been defined an optimized power plant configuration, disregarding any constraints represented by existing equipment to be re-used, considering also the present best available technologies.

Power and steam demand shown in Table 8-6 have been taken as a basis.

The power plant has been designed to be normally operated synchronized and in balance with the grid and with the refinery and such that no import/export of steam is required during normal operation. However, steam demand has higher priority over electricity demand, since refinery electrical demand can be provided by HV grid connection back-up.

Power plant configuration for Base Case 4 is a combined cycle. The configuration of the gas cycle foresees three Gas Turbines 45 MWe frame (ISO conditions) operating at 69% load. Exhaust gases from the gas turbine are post fired to enhance the HP steam production in the Heat Recovery Steam Generators (HRSG). HP Steam leaves the HRSGs at the condition required by the refinery units. Natural gas only is fed to the Gas Turbines, while refinery fuel gas is fed to HRSG.

HP Steam produced by the HRSGs is routed to the Steam Turbines for power and MP/LP Steam generation. For Base Case 4, an auxiliary boiler normally operating at the minimum load has been foreseen to ensure that the steam supply to the refinery is not compromised when a gas turbine (and the corresponding HRSG) trips or is in maintenance. Steam generated by the Auxiliary boiler goes directly to the common HP header before being sent to the steam turbines.

In Base Case 4, Steam turbines are backpressure type. MP Steam is generated through a medium pressure extraction and desuperheated to the temperature required by the users. Exhaust steam from the steam turbine is almost completely sent to the battery limits as LP steam export to the refinery users, except the amount needed from the deaerator for BFW generation.

There is no cooling water consumption, since there is no steam condenser.

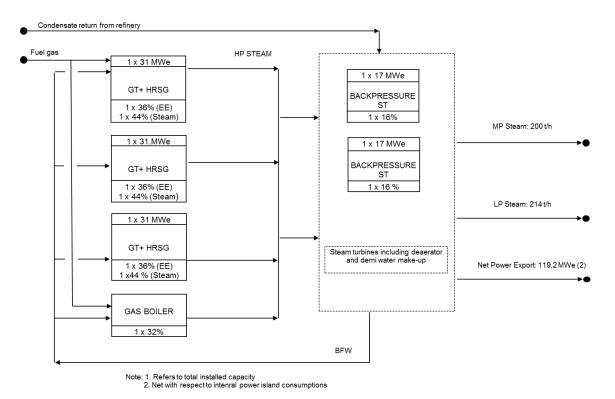
Power plant configuration considered for Base Case 4 is shown in Figure 8-8.

Base Case 4 power plant major equipment number and size are summarized hereinafter:

- 3 x 45 MWe GTs normally operating at 69% of their design load (corresponding to 31 MWe) plus 3xHRSGs normally producing 122.8 t/h HP Steam;
- 2 x 20 MWe Steam Turbines normally operating at 85% of their design load (corresponding to 17 MWe each)
- 1 x 130 t/h Auxiliary boiler normally operated at 30% of the design load (corresponding to 39 t/h), assumed to be its minimum stable load.



#### BASE CASE 4



#### Figure 8-8: Base Case 4) Power Plant simplified Block Flow Diagram

The system has been conceived to have such an installed spare capacity both for power and steam generation to handle possible oscillations of power and steam demand from the refinery users and to avoid refinery units shutdown in case of one piece of equipment (gas/steam turbine or boiler) trips or is in maintenance.

Total installed spare capacity is summarized hereinafter:

- Gas Boilers + HRSG (Steam) +64%
- Steam Turbines + Gas Turbines (Electric Energy) +40%