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Petroleum Refining & Marketing (Package # 06)

➥ Refinery Recommendation report

SOFRECO

in association with

srgb

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Abbreviations

AFRA	Average Freight rate Assessment
AG	Arabian Gulf
API	American Petroleum Institute
BBL	Barrel (159 liters)
Bensat	Benzene Saturation Unit
BPC	Bangladesh Petroleum Corporation
BRME	Balancing, Modernizing, Replacing and Expansion
BSC	Bangladesh Shipping Corporation
CBM	Cubic Meter
CCR	Contineous Catalytic Reformer
CDU	Crude Oil Distillation Unit
CHP	Combined Heat and Power Unit
CIF	Cost Insurance and Freight
CPA	Chittagong Port Authority
CST	Centistoke (Kinematic Viscosity)
DCU	Delayed Coking Unit
DOJ	Dolphin Oil Jetty
DSU	Desalter Unit
DWT	Dead Weight Ton
EPC	Engineering, Procurement and Construction
ERL	Eastern Refinery Limited
EU	European Union
FBP	Final boiling Point
FEED	Fron End Engineering and Design
FOB	Free on Board
HCU	Hydrocarbon Unit
HCU	Hydrocracking Unit
HDS	Hydrodesulphurisation Unit
HOBC	High Octane Benzine Component
HTU	Hydro Treating Unit
IBP	Initial Boiling Point

IOCL	Indian Oil Corporation Ltd
IP	Institute of Petroleum
IRR	Internal Rate of Return
Isom	Isomerisation Unit
KPa	Kilopascal
LNG	Liquidized Natural Gas
LPG	Liquid Petroleum Gas
Mbpd	thousand barrel per day
MEMR	Ministry of Energy and Mineral Resources
MHC	Mild Hydrocracker Unit
MI	Main Marketing Installations at Chittagong
Mln	Million
mmBTU	Million British Thermal Unit
Mmscft	million standard cubic feet
MS	Motor Spirit
MT	Metric Ton
MTBE	Methyl Tertiair Butyl Ether
MW(h)	Mega Watt/(hour)
NCI	Nelson Complexity Index
NGC	Natural Gas Condensate
NPV	Net Present Value
OGJ	Oil and Gas Journal
OPEX	Operating Expense
PMS	Petroleum Management System
ppb	parts per billion (1/1.000.000.000)
ppm	parts per million (1/1.000.000)
PSA	Pressure Swing Adsorption unit
RO	Reverse Osmosis plant, also ARO
ROC	Return on Capital employed
RON	Research Octane Number
RVP	Reed Vapour pressure
SCR	Semi Regenerative Catalytic Reformer
SKO	Household Kerosine Oil
SPM	Single Mooring Point
SRU	Sulphur Recovery Unit
SSREC	Single Stage Recycle (type HCU)
TCU	Thermal Cracker Unit
VBU	Visbreaker Unit
VDU	Vacuum Distillation Unit

VGO	Vacuum Gasoil
WS	World Scale

Refinery Executive summary

The Recommendations report follows the Assessment report and is the logical next step. It is a review of various refinery scenarios and recommendations thereof.

The main conclusions of the existing assessed situation are that ERL refinery is a very small refinery with a simple configuration, and built with now outdated technology. Parts of the complex are less energy efficient. Furthermore ERL refinery cannot maintain its economic viability or sustainability in the longer term as the actual refiner's margin of the ERL configuration is not sufficient valued even at international market parity price.

At current oil product consumption level of 4.0 million ton/year, ERL can meet only one-third, and that contribution will shrink further with the expected sharp increase in future demand. ERL has adequate storage capacity for crude oil and local refined products and together with the main marketing installations at Chittagong can handle all current required imported products volume. This existing oil infrastructure will be important for enlargement of refinery capacity.

ERL's crude supply is costly due to the shallow 9 m draft restriction in Chittagong harbour and the whole refinery supply relies on an expensive and time consuming lightering operation. The initiative to build at Kutubdia deep draft (17 m) water a Single Mooring Point (SPM) with pipeline connection to Chittagong will be an important asset to relieve the crude oil supply bottlenecks. These were the main aspects of the assessment study.

The recommendations will work towards providing answers to the main question of how to meet the future Bangladesh petroleum oil product supply and demand in an environmentally safe, efficient and economically sensible manner.

Improvements in the petroleum product availability by enlarging the refinery and increasing conversion capacity of the refinery will use the following important considerations and requirements:

- A positive net refinery margin for a sustainable operation in the medium to longer term so that the refinery should be able to compete with and replace current imports from other refineries in the region.
- The domestic petroleum product prices must reflect the international oil markets related price benchmark as minimum market price parity.
- A future demand volume scenario that is estimated at 6 million ton/year (minimum) of overall petroleum products, with Kerosene and Diesel as the main demanded products. For refinery feedstock there will be a variety of crude oil types, that will include local produced Gas condensates.
- A petroleum product quality that is in line with the regional requirements and sulphur, nitrogen, carbon soot and other emissions of the refinery to be in line with regional environmental standards.

- Minimal investment requirements in the oil infrastructure surrounding the refinery; oil storage, harbour and jetty facilities and maximum utilisation of current existing equipment and installations. This will assist to find a realistic financing and investment source for the refinery expansion.

The recommendations must use some basic and rational assumptions.

- Petroleum products and crude oil, all will be valued and priced at Platts Free on Board (FOB) Singapore and the Platts quotation for the respective crude at FOB loadport plus freight to a SPM at deep draft Kutubdia anchoring.
- The SPM will be the focal crude oil reception point for pumping to Chittagong. The SPM project with at least 3500 cbm/ hour SPM discharge capacity is not part of this study, but it's a vital element that the study supports and its depreciation is part of the operating expenses.
- Net Product imports will be mainly sourced from the Arabian Gulf (AG) region as FOB AG product purchase price plus tanker freight cost is on average the best arbitrage option and lowest cost possible for destination Chittagong.
- The cost of capital, or the mark-up, will follow the current regional assessment which is at least the going Asian midterm Bond market rate at approx 5.5% currently. All storage facilities at ERL and Main Marketing Installations at Chittagong (MI) in Chittagong will be assumed as being one large terminal and be used together for all refinery storage and in-out movements.

The recommendations are based on a number of Scenarios, each defined by the type of refinery configuration and the underlying aspects such as country's products demand (fixed in all cases) compared with under that scenario, refinery supplied volumes, the efficient use of storage/other logistic facilities and longer term economics.

In all Scenarios the resultant product imbalances and needs for import and the overall economics of the operation will be reviewed, based on refining margin and the import margin results.

Finally there will be an estimate of the quality of the refined products, and resulting refinery emissions, the crude oil types that will be required, including the entire local produced Nat Gas Condensate. For each scenario, refining units' requirement, investment, location and logistics availability will be looked into.

The overall product demand basis, as reported in the assessment report, has been estimated for the medium term (2011-2016) to meet demand expectation to a 6 million ton/year of mainly distillate products (over 70%).

The study also reflects on alternative energy sources other than oil, such as Liquid Natural Gas (LNG), Liquid Petroleum Gas (LPG), and Electricity imports. These alternatives have an influence on future energy supplies and are relevant to the study but will not be further discussed in detail. Main observations/conclusions on alternative energy resources are noted below:

- Electricity import for Bangladesh is questionable given the Indian subcontinent's own demand shortage for the coming years.
- LNG or Liquid Natural Gas import is a good opportunity as LNG Import prices are below those of crude oil and oil products. However the infrastructure required to effect LNG imports needs to be built at massive costs exceeding 1 billion USD.
- The infrastructure and (road) transport for LPG imports are less costly. LPG can provide an alternative to be used beside household use, also as an automotive fuel.

The refinery recommendation study will consider five Scenarios and will make recommendations on that basis. These scenarios are as follows:

Scenario 1: Base Case: Current ERL configuration and purchase of refined products.

This is an analysis based upon a case where ERL refinery is not modernized and continues to operate at 1.3 million ton/year as it has done over the past years. All deficit products to the full 6.0 million ton/year products demand will be purchased from AG and other refineries, shipped into Chittagong on small 25.000 ton product vessels that just meet the 9.0 m harbour draft limitation.

This scenario will not be realistic as the oil importation potential through Chittagong port necessarily with small 25.000 ton vessels is limited and refining and import costs are not sustainable.

Scenario 2: Low investment case aimed to return to positive refiners margins with moderate improvement of the existing ERL Refinery

This Scenario is based again on the existing ERL refinery, but with new (distillate rich) type of crude oils in the crude oil feedstock slate, like Forcados, and all available Nat Gas condensate. Scenario 2 is focused on ways to initially increase the Distillate output and achieve better operating efficiencies further reducing costs, without major investment in new facilities and a moderate increase in production capacity from 1.3 to 1.6 million ton of products /year.

This scenario will still leave too much product vessel movement into Chittagong harbour and is not realistic, but the refinery itself becomes profitable and longer term sustainable. Net imports volumes are still high and costly.

Scenario 3: Modest modernization and substantial increase of production capacity at the current ERL refinery site.

This scenario has the provision of a 100.000 barrel/day CDU but no major residual upgrading units. This is just an essential increase in Crude Oil processing capacity with only vital support units such as a Platformer, Isomerisation unit, and the reactivated small desulphurisation unit. Investment is therefore moderate at 230 million USD. Since existing refinery of 33,000 bbls/day is assumed to be kept on stand-by, products out-put will be that from 100,000 bbls/day crude processing in the new refinery.

The required volume of purchased products will decrease while at the same time other non demanded products will have to be exported. Crude oil will be imported via an SPM near Kutubdia Island in deep water (>17 meters) anchoring. This Scenario will greatly relieve Chittagong port and most products are produced at the refinery. There is no conversion to upgrade the Fuel oil into Diesel and Kerosene, nor is there a Hydrodesulphurisation to reduce the sulphur content to the desired specification of 350 ppm.

Scenario 4: Full modernization of ERL refinery with addition of new units

This Scenario is a refinery configuration design with capacity expansion to 133.000 barrel/day (= 6.0 million ton/year) and investment in upgrading facilities. Because of that there is significant extra Diesel production. Expansion is at the existing (enlarged) ERL location in Chittagong.

This refinery (old ERL units plus new investment in 100000 barrel/day distillation and deep conversion) will maximise the production yield towards distillates, meet all product quality specification standard for the region and provide sufficient profitability to sustain long term survival.

It will make maximum use of all existing Chittagong based facilities (storage and other logistics) to minimise some required additional investments in crude oil and intermediate product tanks and logistics for this configuration.

This is a state of the art refinery with latest and very efficient technology. Investments will be substantial but still moderate at 720 million USD (without acquisition cost of extra land. This scenario assumes completed SPM facility in deep draft water). It requires major financing, but this sustainable refinery enterprise in the long term will provide the financial backbone for the project justification.

Such a configuration could also serve a new build petrochemical industry with quality feedstocks, creating further economic activities for Bangladesh.

Scenario 5: Strategic Development of a new Refinery complex at a different location in Bangladesh.

This scenario looks at a different location for an entirely new refinery, similar in configuration as in scenario 4 and therefore will produce the same products and has all other benefits.

The location is either very close to deep water at Kutubdia to reduce the SPM investment costs, so far assumed to be completed and located in the Kutubdia region or close to the main consumption centre near Dhaka. Immediate consequence is a 400 plus km long pipeline connection for the crude oil supplies upto outskirt of Dhaka.

The Kutubdia scenario requires the construction of a new port with all facilities which is a very expensive infrastructure only affordable if other industries will also make use of this.

If Dhaka site is considered, then a new 350 acre site needs to be developed with all the facilities.

Scenario results with Key Indicators as per the table below:

Scenario description		1 base case	2 minor mods	3 new 100 cdu	4 complex 133	5 new location
Location		Chittagong	Chittagong	Chittagong	Chittagong	Near Kutubdia
Refined products	mln ton	1,3	1,6	4,5	6,0	6,0
Net product imports	mln ton	4,7	4,4	1,5	0,0	0,0
Imbalances	%	1,3%	1,3%	8,8%	16,2%	16,2%
Total prod import bill	**mln $**	**3086,2**	**2868,7**	**1112,5**	**0**	**0**
Refiners margin	mln $	-6,1	12,7	-10,6	162,8	147,8
Trading margin	mln $	-39,9	-37,5	-12	-11,7	-11,7
Total margin	**mln $**	**-46,0**	**-24,8**	**-22,6**	**151,1**	**136,1**
Investment requested	mln $	2,6	15,6	230,3	718,2	791,2
Net present value	mln $	-349,2	-201,7	-268,0	722,0	652,8
IRR	%	na	na	na	32%	27%
Repayment amount 10 year annuity loan	mln $	$0,3	$2,1	$30,6	$95,3	$105,0
Spm		no	no	yes	yes	yes
Lightering crude oil		yes	yes	no	no	no
Port traffic		unrealistic	unrealistic	normal	light	new port
Prod quality		poor	improved	improved	meet region	meet region
Sustainable operation		no	almost	almost	yes	yes
Nelson index		2,3	2,5	2,4	7,6	7,6

The prime recommendation is Scenario 4, which provides the best future product supply with the highest Net present value and internal rate of return. The 6 million ton/year deep conversion refinery resembles recent projects in Vietnam and UAE and provides guidance for implementation of the construction and FEED (front end engineering and design).

This recommended refinery in Scenario 4 is configured with latest technology units:

	Approx. cost in USD mln
New 100.000 bbl/day CDU (incl. LPG Merox)	101.0
New 45000 bbl/day Vacuum Distillation Unit	65.4
New 5000 bbl/day Cont Regenerative reformer (CCR)	35.3
New 5000 bbl/day Isomerisation Unit	9.3
New 10.000 bbl/day Naphtha Hydrotreater	9.9
New 20.000 bbl day Hydrocracking Unit (Chevron Lummus)	1 61.9
New 50.000 bbl/day Hydrodesulphuriser	98.5
New 15.000 bbl/day Thermal Cracker	51.8
New Amine treatment Unit (60 ton s /day)	7.7
New Sulphur Recovery Unit (60 ton s /day)	18.4
New Hydrogen Unit (12 mmscft/day)	17.8
Gas turbine CHP unit 3*10 +7 MW/h and 450 ton/d steam.	24.9
Crude oil storage 100.000 cbm	11.5
Distillate storage 45.000 cbm	5.0
Fuel Oil storage 30.000 cbm	3.6
LPG sphere plus pressure control valve/unloading rack	3.2
Water Treatment Unit 400 t/d	2.0
API oil/water separation	0.5
Flare expansion	0.2
ERL current unit refurbishments and modernisation	15.0
Investment for Scenario 4	652.9
Contingency 10%	65.3
Total estimated investment Scenario 4	**718.2**

Scenario 3 is also an option but only as a start and has to be complemented later with residue upgrading units.

Scenario 5 is the second best alternative, but will require extra funds to build the necessary infrastructure at a entirely new location. This may be an option if other private sector parties including non-oil trade and industry join the financing of the overall project.

Policies and regulation are very important for the ultimate decision. A market related parity pricing used for the domestic market should be followed with some taxation to encourage efficient energy use. It also provides the state with funds for redistribution to targeted groups as a subsidy (agriculture and public transport) or even provide funding for the refinery project.

Private parties should be participating and allowed to operate in the domestic refined products market as distributer or as refiner with their own funding.

The government may consider some form of minimum price setting, but a general below international market price setting will undermine the long term sustainability, inefficient energy use and huge losses for the state or no willingness from the private sector to participate in investments.

The study also recommends the necessary changes in all involved organizations to reflect the increased complexity of the future energy supply operation and that in itself is a great step forward to obtain sufficient professionalism in the oil supply for the country.

The conclusions from this study are as follows:

- That without any implementation of a substantial increase in overall refinery capacity in the very near future the refined product importation will reach its maximum level possible. That will put a ceiling on any needed further petroleum product consumption and will act as major impediment for economic growth in Bangladesh.
- The current product supply then rests entirely on importation and this is a costly and loss making affair and not sustainable even in the short term.

The ultimate choice for the future; a fully modernised, sustainable and technologically advanced refinery is a function of investment capital available. The preferred site for such a refinery is Chittagong adjacent to existing ERL refinery which will ensure maximum utilization of existing facilities of ERL and marketing companies (POCL, JOCL, MPL).

A Grass Root Refinery of similar configurations of Scenario 4 can be built at a different location other than Chittagong with possible or even strongly recommended participation of private sector based on international market parity price. Naturally, this project will cost much higher and needs to be thoroughly evaluated.

Financing either Scenario 4 or 5 by the private sector and commercial banks will require sufficient positive margin and de-regulation of domestic market pricing. Alternatively the state may initiate the investment out of its own funds. All major investment will require a commercial rate of return to justify.

No action on the BMRE and in particular E(expansion) project and a mere continuation of the present ERL refinery runs is not an option for safeguarding and improving the countries future energy supply.

1. Introduction

In the refinery assessment report a thorough review was carried out about the current status of the refining activity in Bangladesh.

This study evaluated the refinery output volume being in a major imbalance and shortage with current product demand, due to the production yield and also the overall limited refining capacity. Furthermore the financial longer term sustainability was reviewed in a current refiner's margin realisation analysis. A detailed analysis of the refinery unit and utility efficiency, the refinery operating costs, and the overall logistic limitations were also made.

However the assessment provided no answers to the question what should be the refining activities in the country in light of the medium and longer term future of the Bangladesh energy supply and demand.

In this study the focus was on a future model for setup of refinery and storage facility in Bangladesh.

1.1 Main Assessments of the current Refinery Operation

As a basis for the recommendations the observations and conclusions on current refining activities and existing logistics/infrastructures of Chittagong are to be used.

Salient parts of these observations/conclusions are reproduced below:

- ERL refinery is a very small refinery of very simple configuration, and built with now outdated technology. Parts of the complex are less energy efficient.
- The actual refiner's margin of the ERL configuration is not sufficient to guarantee a sustainable long term financially independent and healthy operation. At best the refinery can expect a break even situation which has no contribution to new investment needed.
- At current demand level, ERL can meet only one-third of the current petroleum product's demand of the country, and that contribution will shrink further with the expected sharp increase in demand.
- ERL acts as a proven fall back system and the refinery provides, although here for a minor share, a reasonable energy security if secure imports are being included as part of the total supply. It should also serve to process locally produced Natural Gas Condensate.
- Except the Visbreaker Unit and Bitumen blowing Unit (part of Asphaltic Bitumen Plant) all other process units are undersized in proportion to the crude Distillation Unit (CDU). Both Visbreaker Unit and Bitumen Blowing Unit have some spare capacity. The whole refinery is very small when benchmarked against international standards.
- ERL has adequate and comfortable storage capacity for crude oil and locally refined products. The three oil marketing companies have more than adequate storage capacity to handle comfortably all imported products and ERL's products at current demand level. Considering the tankage available at ERL and nearby main installations (MI) of oil marketing companies as a combined tank farm, this can sustain the operation of a much larger refinery.

- Electricity generation capability of ERL cannot be considered comfortable, efficient and reliable. Even to maintain an acceptable on-stream factor for ERL process units, electricity generation capacity efficiency and reliability need to be improved.
- Thanks to good preventive maintenance program, ERL refinery despite its age seems to be in good operating condition.
- Crude supply to ERL is costly due to the shallow 9 m draft restriction in Chittagong harbour and the whole refinery supply relies on an expensive and time consuming lightering operation.

1.2 Criteria that will guide the approach to future oil product supply

Any improvements in the petroleum product availability by enlarging the refinery and or other facilities should be evaluated against the following key considerations:

- A positive net refinery margin for a sustainable operation in the medium to longer term. This was explained and analysed in the assessment report that a refinery operation, in order to be successful in the long term, has to be generating a minimum sufficient cash flow to guarantee its existence and replace depreciated units. Such refinery will be able to compete with imports from efficient refineries in the region and will at all times be focussed to minimise its costs, while selling at the international market prices. The internal Bangladesh petroleum product prices will be reflecting this market related benchmark.
- A supply volume scenario that should not be less than 6 million ton/year of overall petroleum product, with aviation fuel, Kerosene and Diesel being prioritised.
- Maximisation in the refinery output of distillate production; Jet fuel, Kerosene and Diesel. This is important to meet the exceptionally distillate oriented Bangladesh demand pattern. Refineries can be designed to produce almost any demanded yield, but cost effectiveness will limit this degree of freedom. In this study a careful consideration will be made at all times between cost and benefit.
- A realistic financing requirement for investments in the Petroleum Downstream Sector in a country like Bangladesh, building of refineries and in general refinery related infrastructures are large investments and will be restricted by bank capital available. The study will take a realistic demand for funds into account.
- A reliable and independent source of crude oils, including locally produced gas condensates, with active trading of inevitable petroleum product imbalances is prime requirement. Although annual demand 6.0 million tons of oil is substantial, compared to the Singapore regional consumption areas it is less than 1% and too insignificant to pose limits on availabilities of crude oil and/or refined products.
- We have to assume a petroleum product quality that is in line with the regional requirements and environmental protection in general will be ensured in Bangladesh. Adoption of the main regionally accepted product quality standards will have to be considered.
- Sulphur and other emissions from the refinery to be in line with regional environmental standards.
- Minimal investment requirements in new build oil storage, harbour and jetty facilities and maximum utilisation of current existing equipment and installations.

With these considerations there are assumptions that will provide the frame within which the recommendations can be formed, evaluated and tested on realism.

1.3 Assumptions that will underlie the recommendations

- Petroleum products and crude oil. Petroleum products in Bangladesh, imports and ERL production at Chittagong port and MI storage facilities will be valued at Platts FOB Singapore as the **import parity** basis. A full analysis of the correctness of this assumption was given in the refinery assessment report. Crude oil and other feedstock intermediate product purchases are valued at the respective Platts FOB quotation or derived from Platts.
- Crude oil supply will be made through deeper draft water anchored SPM jetty with a pipeline connection to Chittagong. SPM project is an approved one and is currently at primary stage of implementation.

  We will assume here that this SPM project will be executed in light of Chittagong port congestion, and refinery expansion and enlargement for at least 3500 cbm/ hour SPM discharge capacity. The investment cost is not part of this study; only its depreciation is included in the operating expenses of the refinery.

  As an alternative way of crude oil supply there is a possibility (to be studied) to use large 50.000 tons lightering vessels that sail from the Kutubdia anchored mothervessel to a 12-13 meter draft point in the Sandwhip channel at Chittagong and transfer from that point by a short pipeline to the refinery.
- Product purchases will be mainly sourced from the Arabian Gulf (AG) region as product purchase price plus freight cost is on average the best arbitrage option and lowest cost possible for Chittagong destination. On average, freight for small 25.000 ton product tankers for the voyage AG-Chittagong was assessed at 22.50 USD/ton. Freight for crude oil vessels from the AG to Kutubdia Anchoring is assessed at 13.00 USD/ton. (And lightering to Chittagong at 5 USD/ton).
- Crude oil and products availability is not limited to meet the Bangladesh small scale oil demand.
- In place of the current inefficient lightering procedure for crude oil, this study assumes direct discharge at the current jetties for products. Any further improvement will mean lower costs for all recommendations.
- Product export will be valued at Platts Fob Singapore quotations less the cost of freight from Chittagong, Bangladesh to Singapore. Platts Singapore is the highest and also most active valued market in the Indian/Asian sub continental region.
- Cost of capital/mark-up will follow the current regional going rate which is at least the going Asian mid term Bond market rate at approx 5.5%. Although for Bangladesh as a Standard&Poor BB- rated country the rates will be higher.
- All Storage facilities of ERL and MI and other physical capacities in Chittagong, will be considered to act together for storage and in-out movements, which is a recommendation in itself.

The recommendations will take these key considerations and assumptions into account and ideally will satisfy all conditions.

1.4 Variables that can be changed to increase / change output

Under BPC/ERL's control, to change the oil product output and the overall volumes available, there are a few variables that can be changed to achieve the recommendation for that:

- Modify and debottleneck and improve efficiency of existing refinery facilities.
- Change the refineries mode of operation, including the product purchase.
- Change the type of crude oils in the refinery base feedstock slate.

- Invest in new refinery process units and other logistics facilities and distribution units.

We have defined the existing situation in the assessment report. The criteria that should be considered are defined, together with the underlying assumptions. All these and the refinery variables set the boundaries in which area this study has been carried out.

1.5 Recommendations Structure

The approach for the recommendations will follow a number of **Scenarios**, each defined by the type of setup of refinery facilities, or refinery configuration.

Start point and Base Case is the current ERL refinery configuration, as described in the refinery assessment report.

Each refinery expansion scenario will discuss:

- Demand (fixed in all cases at 6.0 million ton/year) compared with under that scenario's refinery supplied volumes.
- The required refinery units, mode of operation and use of storage/ other logistic facilities.
- The imbalances and shortages/surpluses between supplied and demanded volumes.
- The economics of the operation, based on refining margin and trading margin concepts.
- The quality of the refined products, and resulting refinery emissions.
- The crude oils required, including the Nat Gas Condensate.
- An estimate of investment requirements.
- The location and immediate infrastructure.

The scenarios that have been studied are:

1. Current ERL configuration and purchase of refined products: Base Case

The existing ERL operations have been used in this scenario. This scenarios in essence is assessed actual refinery output yield: actual crude oil types purchased and operational costs (as discussed in the refinery assessment report), added with volumes of purchased products to meet the full 6.0 million ton demand.

This scenario is the base case for the recommendations since it does not require any refinery investments.

2. Moderate Improvement of the existing ERL Refinery

This Scenario is focussed on ways to increase in Distillate output and better operating efficiencies, **without major investment in new facilities.**

Basis is the existing ERL refinery operation, but with the introduction of new (distillate rich) crude oils in the crude oil feedstock slate, like Forcados, or similar, Natural Gas condensate and possibly other Mid Eastern crude oils.

Each probable crude is reviewed on its feasibility, both technical and its economics of the refiners' margin, taking into account its specific feedstock costs (incl. transport) and synergy on the overall operation.

The main changes from the base case are:

- Debottlenecking of the existing Crude Distillation Unit's overhead and rectification and stripping section.

- Debottlenecking of the Vacuum Distillation Unit by adjusting the vacuum and condensing section.
- Enhance the Platformer capacity and severity of the process by raising/lowering the pressure and/ or severity over the reactors.
- Also to return the current inoperative Mild Hydro Cracking unit back in service at lower pressure and in a more hydro treating than cracking service for very light Vacuum Gasoil's only.
- Improve the power generating utilities.
- Use different crude oil types with better yield of distillate products

In addition we will review a change in the performance of Platformer and Visbreaker. The first to produce high octane gasoline components to produce 95 RON gasoline finished grade, the second to increase distillate production. Furthermore the aim is to increase Jet Fuel, Diesel and Kero distillates and improve gasoline blending and production with existing equipment, and avoiding the (costly) export of small shipments of Light Naphtha.

This scenario will not substantially increase the availability of refined products, but will improve the refinery economics.

3. Modest modernization and increase of production capacity at the current ERL refinery site

This scenario will recommend, where required, improvements, modifications and adjustments to the ERL refinery configuration with a view to enhance the technical and in particular the volumetric operation of the refinery. This scenario will include the Balancing, Modernizing, Replacing and Expansion (BRME) of the facility. There will be no major conversion units but just an essential increase in Crude Oil processing capacity. Refinery economics will remain depressed as crude distillation alone is not returning positive margins. However investment is modest and volumes in particular Diesel is increased significantly. It will reduce the purchased volumes and save on expensive products purchase and freight cost. This scenario will also look at a different crude oil base slate, aimed for direct contribution towards distillate production and sulphur reduction in distillates.

4. Full modernization of ERL refinery with addition of new units to be build

This scenario will consider both capacity expansion and yield improvement at the existing ERL location.

Investment will be substantial and requires major financing, but also the refiner's margin and product volume output will improve which will provide the financial backbone for the project justification.

- Add to the existing ERL configuration at Chittagong a second Crude Distillation Unit (CDU) of 100000 bpd (depending on the product demand forecast), capable to produce as much as 6 million Metric tons.
- Add a corresponding new Vacuum Distillation Unit (VDU) capacity,
- Add a new CCR Platformer, and for the Light Naphtha an Isomerisation Unit also capable to process the stripped gas condensates from the Gas fields besides the CDU light naphtha.
- Add a Hydrodesulphuriser / in combination with a Mild Hydrocracker capable to reach 80-130 bar which will process an extra gasoil cut from the CDU 350-to 380 deg C plus the light and medium Vacuum Distillation Gasoil.
- For a new and reliable power generation system, capable to expand the utilities which could be based on a Cogen. efficient Combined Heat Power Gas turbine facility allowing efficiencies far exceeding the conventional system now in place.

For other services in oil movement there will be a review of all current ERL facilities like storage facilities, pipelines, jetties, flare, oil catchers, water, and smokestacks to be used in an enlarged processing capacity scenario where possible.

5. Strategic Development of a new Refinery in Bangladesh

The previous scenarios have dealt with the existing ERL facilities in an increasing complexity of modernisation. In that review the refinery location remained at Chittagong in all modernisation scenarios to fully benefit from the existing infrastructure. However this leaves the current refining location with the limitations of draft and possibly more storage and unloading facilities.

The possible construction of a new facility must take these disadvantages into account. With regard to the latter, the following aspects (not limited to) will be analyzed:

- Size of the refinery (first phase and long term evolution);
- Location (taking into account the geographical and port conditions and the location of the main market centres);
- Technical structure of the refinery (operational facilities, process units, offsite facilities); and optimal crude oil base slate.
- Downstream infrastructure required to transport and store the products;
- Stay open for expansion into Petrochemical areas if justified (Naphtha and Gas condensates as Steam cracking feedstock for polyethylene/propylene manufacture).

An entirely new refinery complex close to deep draft waters will be reviewed in this scenario near Kutubia Island to benefit from a short stretch Single Point Mooring with at least 17 m draft and avoiding the expensive problem of lightering the crude oil supply vessel.

The new refinery would benefit from the advantage of latest technology, similar to recently built refineries in Vietnam and Middle East.

A new CDU, VDU, Continuous Catalytic Regenerative Platformer (CCR), a Penex Isomerisation unit, a one or two stage Mild/ or even Resid Hydrocracker and a soaker drum equipped new Thermal Cracker, similar as proposed in Scenario 4.

This project will evaluate the associated costs of a grassroots build refinery with cost guidance from Petro Vietnam's 2009 Dung Quat refinery and 2007 Sohar refinery in Qatar. The total costs will include the marketing logistics cost to inland terminals from a location like Kutubia preferably via a dedicated products pipeline from the refinery to Dhaka and further North.

Of course this last Scenario will be the most expensive of all options.

Modernization of the just the existing ERL configuration will be less capital demanding but may not produce sufficient new volume at low cost nor may it allow further expansion if demand in the long term future increases further.

1.6 More about Key Considerations and Assumptions

1.6.1 Setting the volumetric basis for the petroleum demand

Probably the most important decision point for a recommended refinery scenario is setting the parameters for meeting the large imbalance in supply and demand tonnage of petroleum products.

This is even the situation today where only 35% or one third of current demand is produced by the current ERL refinery. The refined product importation from abroad of over 65% today is a significant quantity.

In our assessment reports we have indicated a growth rate for the main sectors; transport, industry and power generation, oil demand of over 6% on year to year basis.

It is therefore a necessity to look at least into consideration the near to medium term future and use a for Bangladesh realistic volumetric demand expectation for petroleum products. Of course it is not only the total quantity, but also the future demand yield that will set the boundaries for the recommendation.

2009-2010 FY petroleum products consumption was just over 3.8 million tons (excludes imported volumes of Bitumen, LPG and Lubricants) of which almost, over 86% is Distillates; Diesel and Kerosene's (Jet Fuel; and household Kero).

Meeting such an unusual demand pattern by a specific distillate geared tailor made refinery configuration is impossible. Even with dedicated to distillate type crude oils, and the latest refining conversion technology available such a production yield is neither achievable nor realistic to design.

In the assessment report a medium term product demand was derived following all available information, inputs from BPC, and other professional organisations in Bangladesh.

These demand volume projections were discussed during the assessment reports and stakeholders information meetings on 12 and 13 December 2010.

Product	Sectors:	Power	Industry	Agric	Road Transp	Air Transport	Res & Com	TOTAL
Jet Fuel						286,900		286,900
Premium					85,500			85,500
Regular					127,200			127,200
Kero							376,600	376,600
Diesel		121,561	72,125	820,427	1,494,437		59,650	2,568,200
Fuel Oil		210,800	75,000					285,800
other								122,000
TOTAL		332,361	147,125	820,427	1,707,137	286,900	436,250	3,852,200

Reference year consumption FY2010

Projections:

FY2015

Sector>	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	TOTAL
POL								
Jet Fuel					357,530			357,530
Premium				125,000				125,000
Regular				165,000				165,000
Kero						376,600		376,600
Diesel	860,954	94,612	1,113,971	1,855,918		22,720	24,209	3,972,384
Fuel oil	2,283,595	95,969					100,742	2,379,564
TOTAL	3,144,549	190,581	1,113,971	2,145,918	357,530	399,320	124,950	7,376,077

FY2020

Sector>	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	TOTAL
POL								
Jet Fuel					445,547			445,547
Premium				152,082				152,082
Regular				200,748				200,748
Kero						376,600		376,600
Diesel	1,265,024	133,943	1,355,317	2,460,295		22720	32,092	5,269,390
Fuel oil	3,355,350	135,865					133,548	3,624,763
TOTAL	4,620,374	269,807	1,355,317	2,813,124	445,547	399,320	165,640	10,069,129

FY2030

Sector>	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	TOTAL
POL								
Jet Fuel					691,921			691,921
Premium				225,118				225,118
Regular				297,156				297,156
Kero						340,590		340,590
Diesel	2,607,253	263,485	1,967,951	4,242,544		20,548	55,340	9,157,121
Fuel oil	6,915,483	267,266					230,291	7,182,749
TOTAL	9,522,736	530,752	1,967,951	4,764,817	691,921	361,138	285,630	17,894,654

The main contributors to a more 'different' demand pattern compared with the actual 2009-2010 demand pattern are:

- The new product demand for Furnace Oil or Fuel Oil and to a lesser extent the use of Diesel for additional electricity generation.
- The further increase in Diesel for transportation use, cars, lorries, rail etc.
- An increase in Jet Fuel demand.

We believe that increase in demand will occur and therefore the volumetric basis should be sufficiently proactive to assume a Distillate (Kerosene, Jet fuel and Diesel) refined product requirement of around 4.2 million tons (compared with currently 3.3 million tons) and a total oil product demand of approximately 6 million tons per year for the recommendation part of the study.

Main Product requirements for Refining Study Recommendations basis are hereunder:

	Tons/Year
Jet Fuel	350.000
SKO Kero	300.000
Diesel	3 500.000
Other Distillates	50.000
LPG	50.000
Gasoline's	250.000
Vac Residue (Bitumen feed), Residual Fuel Oil (electricity generation)	1500.000 * balancing for refining output.
Total	**6 000.000**

In any refinery, Residual Fuel Oil is a balancing product since the objective or otherwise defined goals will always be to produce as much light and distillate products from a barrel of crude oil as possible in any given refinery configuration. Light products are all higher in value than Fuel oil and for any configuration, simple or very complex. The profit maximisation will drive the refinery yield towards its optimal refining margin and leave the amount of residual fuel as resultant in the production yield.

If the actual demand for Fuel oil is above the refinery production, then this deficit fuel oil will be purchased and because it is the lowest priced product it will be the best choice to purchase. And vice versa, if the refinery produces more fuel oil than required, the balance will be exported.

Some products such as LPG, bitumen, lubricants are imported by third parties and reflect the larger total domestic demand. In the analysis, if extra volumes are made available from increased refinery operations, then that will be used primarily for domestic demand and/or export. Rebalancing will take place with either 3rd party supply or from increased refinery supplies. Refinery economics will not change as domestic prices will reflect international market parity levels.

An ideal basis that will perfectly match the main distillates demand as already said, is impossible for the Bangladesh or any countries current demand yield. There will always be surpluses and deficits, or imbalances. For this reason Oil companies who produce for a local market will have a dedicated Trading or Supply department that balances the products in a sales and purchase operation.

These Supply departments are complementary to the refinery operation itself and as such work as one team. A professional Supply Group operation will be reviewed later in more detail in this recommendations study.

1.6.2 The improvement of the crude oil supply to Chittagong

One of the striking limitations is the draft limitation at Chittagong port. If more crude oil is required for a refinery expansion then the process of lightering is a bottleneck. At this moment some excess capacity at Jetty 6 and 7 may be there, but if crude oil volumes increase from current 1.3 million ton/year to 6 million ton/year, the lightering capacity and also jetty capacity would be insufficient to handle these quantities.

Also a much larger refinery cannot be dependent on the many links in this long supply chain, regardless of the high costs associated, and the risks that one part of the chain is creating a problem.

While crude oil in storage will overcome supply disruptions for a small 1.3 million ton/year refinery operation, there is no real alternative for a much larger refinery.

Possible solutions for this harbour draft restriction were discussed but the one solution is the construction of a Single Point Mooring system in deep draft water with a pipeline connection to Chittagong.

It is understood that this SPM project meanwhile has been approved and will facilitate the refinery expansion recommendations without concerns for the crude oil supplies on a much larger scale.

1.7 Demand Volume Flexibility

By no means is the 6.0 million ton/year demand basis a fixed set of to be produced volumes and target numbers. Refineries are within their operational boundaries flexible and adjustments between the light end fractions can be made. Household Kerosene and Jet Fuel are to a large extent interchangeable within the min/max specifications set by the refinery. Also Naphtha and Gasoline production are each other's substitute and so is the fractionation cut point between more or less Diesel/Kerosene.

It is the total capacity design and the degree of unit sophistication that is important.

- Actual used capacity would still allow crude runs to be below the maximum designed capacity.
- Secondary processing units are usually flexible and can be ran at various degree of severity.
- Storage facilities, Jetties, pipeline capacities can be added in any size or capacity required.

From the current maximum rated and mainly distillation only capacity at ERL of 1.5 million tons/year to a level of 6.0 million tons/year is an important vision for Bangladesh medium term future refinery output.

With current country's oil product consumption at 3.8 million tons/year and with solid expectations of a rapid increase in Fuel oil and Diesel consumption, the 6 million ton capacity may be reached in the very near future.

Oil Demand boosters:

- Economic industrial growth
- Increased (non CNG) transportation use
- Artificially low energy price
- Substitution of Gas use to Oil and Coal.
- Power and electricity generation increase.

Oil Demand reducers:

- Consumer oil price linked to international market levels.
- Taxes and duties on oil consumption
- lower economic GDP growth
- Oil use substituted by Coal/ Gas /nuclear
- Import of Electricity from neighbouring countries.

1.8 Conclusion on future Demand Volumes

Either side of the requirement balance will have impacts if they occur. Some are policy driven and therefore entirely in the hands of policymakers, other items are economically and politically driven. Electricity imports from India, and possibly Nepal are likely longer term developments and may not happen at all for political reasons. Also the country may well want to be independent of foreign electricity imports as a matter of supply security.

Therefore for the recommendations the tentative high Distillate demand yield and total refined product consumption tonnage of 6.0 million ton/year will be the volumetric guideline.

1.9 Alternative Energy Recommendations

This simple setting of an important oil product volume parameter does not exclude recommendation to look at alternative means beside oil refining, although this would fall outside the scope of this study.

There is a brief discussion of 3 major developments as part of the future demand that could be of interest to Bangladesh and will have an impact on the oil demand;

- Electricity imports,
- Natural Gas LNG imports and
- LPG imports for automotive use.

1.9.1 Electricity import

The key aspect for electricity import is the infrastructure and surplus from neighbouring supplier countries. We understand that Bangladesh does not have an import infrastructure at present and would require some investment for electricity imports to become possible.

If import of Electricity is a possibility and is realistic within a reasonably short timeframe then it should be pursued. However the outlook for any electricity import from India does not look positive, instead there is a rather large shortage. With India's GDP per capita of 3300 USD/cap (Bangladesh 1550 USD/cap) and a growth rate of 8.3% expected (Bangladesh 6%) there will be a continuous demand for electricity in both countries. (Source: CIA files 2010).

Due to the fast-paced growth of India's economy, the country's energy demand has grown on average at 3.6% per annum over the past 30 years.

In December 2010, the installed power generation capacity of India stood at 165,000 MW and per capita energy consumption was 612 KWh. (Bangladesh 148 kWh). India annual energy production increased from about 190 billion KWh in 1986 to more than 680 billion KWh in 2006. The Indian government has set a modest target to add approximately 78,000 MW of to be installed electricity generation capacity by 2012 which it is unlikely to achieve.

The total demand for electricity in India is expected to cross 950,000 MW by 2030. According to a research report published by Citigroup Global Markets, India is expected to add up to 113.000 MW of installed capacity by as early as 2017 given its robust industrial growth and success to compete with China in export markets.

In contrast current electricity production capacity of Bangladesh is around 5.800 MW and the Power Development Board has planned to add 3,000 MW permanent capacity in the coming years to 2015, beside a quick rental program of 1,200 MW currently being planned and implemented.

Conclusion on electricity imports

It is unlikely that any surplus from India can be expected in the near to medium term, on the contrary. India with a deficit capacity now of at least 78,000 MW will review importation on a big scale itself until it has fulfilled its investments in (modern generation technology) capacity requirements at least till 2020. There may be some temporary regional surpluses due to India efficiency awareness or growth expectations but overall there will be no strategic electricity import potential for Bangladesh. India with its buoyant economic growth and access to high tech knowledge will be in deficit for its electricity supply for the foreseeable future. http://en.wikipedia.org/wiki/Electricity_sector_in_India - cite_note-10#cite_note-10

1.9.2 Natural Gas Import

Import of Natural Gas as Liquid Natural Gas (LNG) may add to the overall energy supply. Gas will have to be imported as LNG but LNG import is not a simple small scale operation. LNG handling requires specific build large capacity storage tanks, large high tech dedicated vessels and a complex loading and unloading infrastructure, besides a local distribution network.

Brief description and scope of LNG import.

The LNG receiving terminal receives liquefied natural gas from special ships, stores the liquid in special storage tanks, vaporizes (Re-gasification) the LNG, and then delivers the natural gas into a distribution manifold connected to the national pipeline grid.

The unloading facility is often designed to accommodate a wide range of tanker sizes from minimum 87,000 m3 to 145,000 m3. The liquid unloading rate from the ship is usually 10,000-12,000 m3/hr, compared to modern crude oil discharge rates of 7000-10000 ton/hr.

The receiving terminal is designed to deliver a specified gas rate into a distribution pipeline and to maintain a reserve capacity of LNG. The amount of reserve capacity depends on expected shipping delays, seasonal variations of supply and consumption, and strategic reserve requirements (strategic reserves like compulsory oil storage are needed when the terminal may be called upon to replace another large source of gas from either a pipeline or another receiving terminal on short notice).

A full containment LNG tank is one where the annular gap between the outer and inner tanks is sealed. Generally this type of tank has a concrete roof as well as a pre-stressed concrete outer wall. The outer wall and roof now can contain both cryogenic liquid and vapor generated. The weight of the concrete roof permits a higher design pressure [290 mbarg] than a metal roof tank [170 mbarg]. This just to illustrate that LNG is a totally different story and these storage tanks are different by all means than a conventional oil storage tank. They are also very expensive to build.

Double metallic tanks have also been constructed in Japan that can be considered as full containment. The outer tank is made of materials that can withstand LNG and retain both liquid and vapor.

The size of LNG tanks has been increasing over the years. In general the largest common tank size is 160,000 m3 while LNG tanks are seldom below 100.000 m3.

A typical LNG receiving terminal consists of:

- LNG unloading system, including jetty and berth in at least 17 m draft water given the size of the average LNG tanker.
- LNG storage tanks.
- LNG vaporizers, re-gas installations and gas treating.
- In-tank and external LNG pumps.
- Vapor handling system

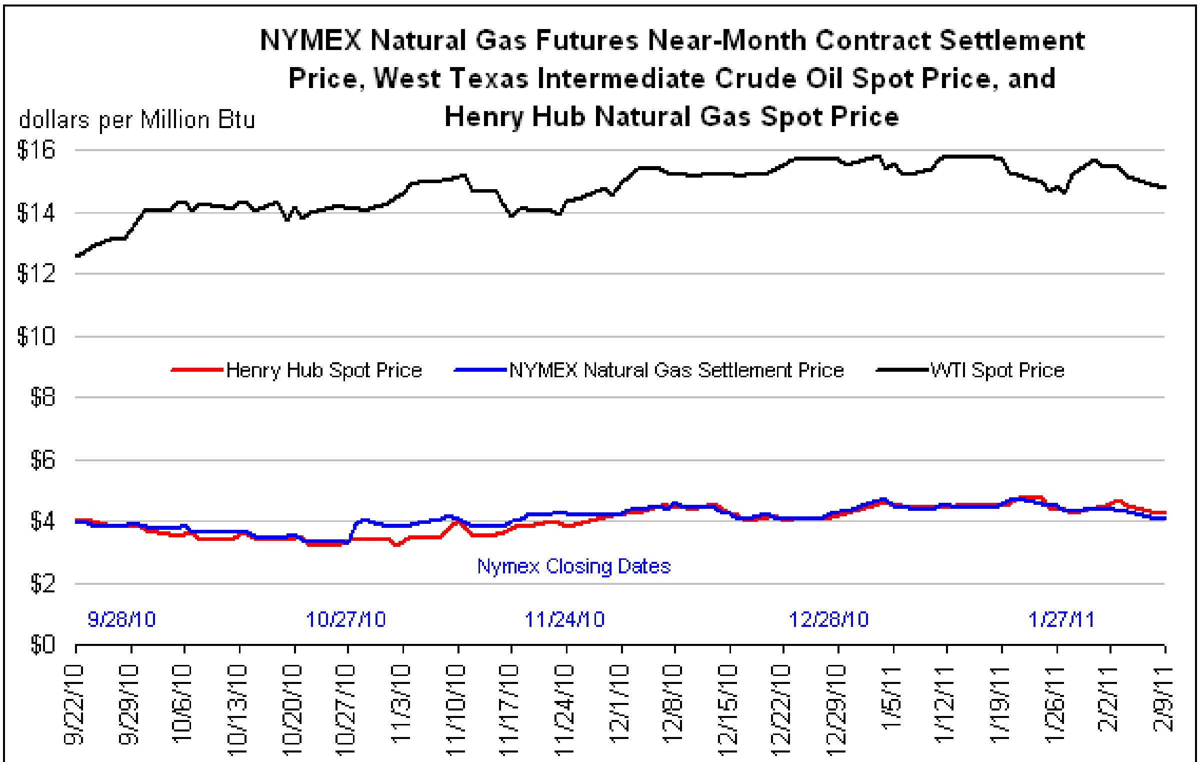
- Supporting utilities, piping, valves, control systems, and safety systems required for the terminals' safe operation.
- New Infrastructure (roads, fencing and buildings) and connections at the distribution manifold into Bangladesh existing pipeline infrastructure.

LNG installations are not a cheap option and initial investment is high. But the cost of natural gas relative to crude oil is very cheap, less than 40% when expressed in USD per million BTU.

The graph below illustrates this price differential, and compares the price of crude oil (WTI, the US marker crude) with the price of Nat Gas both expressed in USD per million BTU.

Gas prices have been less than half of the price of Oil, for quite some time and Gas remains a much desired energy carrier in particular in Bangladesh for CNG, households and Combined Heat and Power electricity generators. In almost all cases provide a much better value than to use petroleum products. LNG availability is good and many LNG export terminals are being built in the world.

LNG import is therefore an option that should be considered by Bangladesh. It bears a direct relationship for the petroleum product demand if Gas import will replace Furnace oil and Diesel for power and electricity generation.



Note: The West Texas Intermediate (WTI) crude oil price, in dollars per barrel, is converted to $/MMBtu using a conversion factor of 5.80 MMBtu per barrel. The dates marked by vertical lines are the NYMEX near-month contract settlement dates.
Source: Natural gas prices, *NGI's Daily Gas Price Index* (http://intelligencepress.com); WTI price, Reuters News Service (http://www.reuters.com).

However the infrastructure to import Gas requires the construction of a LNG plant and the construction of a discharge port. These facilities are very high cost investments.

A LNG export facility costs at least USD 1.5 billion per 1 billion ton per year production capacity, and a LNG import receiving terminal would costs USD 1.0 billion (1.000 million USD) per 1 billion cubic feet /day throughput capacity.

LNG specialized refrigerated and pressurized tanker are generally 150.000 cbm capacity, with construction cost USD 0.2–0.3 billion each and shipping rates to charter these vessels are 3 to 4 times higher compared to rates for crude oil tankers.

Compared with the crude oil market, the Liquid Natural Gas market is very limited in applications other than in and through pipelines and manifolds. There is no easy way to handle this form of energy without a proper infrastructure all the way to the end consumer, unlike oil products which can be carried, stored, and consumed without major costs.

As indication only since locations differ and so does the cost, a recent LNG import and regasification terminal project with a nominal capacity of at least 6 BCM per annum at the Port of Rotterdam is expected to cost over 800 million Euro (1.100 million USD) for the import terminal alone. This excludes the investments in a dedicated construction of mooring facilities within Rotterdam's deep draft port.

For Bangladesh, an investment in the construction of the LNG terminal alone is not going to solve the Gas deficit. It does not account for the in Bangladesh required port infrastructure to accommodate modern LNG vessels up to 17 m draft, nor the capability to unload, regasify and distribute.

SPM installations or similar type of discharge out at deeper draft locations at sea are not possible given the nature of LNG as it requires immediate containment in the re-gasification facility and storage tanks on shore.

Conclusion for Natural Gas Imports

Natural Gas is very cheap, as presented in the graph above, when compared to crude oil.

The international market price for Gas is currently around 4.50 USD/mmBTU FOB (= approx 12 - 14 Taka per NCbm) or less than 40% of the equivalent crude oil price.

However the required investment in LNG infrastructure is well out of proportion compared to for example a new refinery and existing port facilities. Also it is understood that the domestic Bangladesh price for Gas is around 5.80 Taka per NCbm, and thus far below the international market purchase price. Such heavily subsidized gas prices cannot be sustainable by any Government that needs to finance Gas imports, and has to pay for the very high cost LNG installations investments on top.

It would not be within the scope of this study to review the overall Gas economics in detail.

We assume that LNG as an additional source of energy may not be available in the short term and decreasing domestic gas availabilities and new energy demands have to be supplied from oil products.

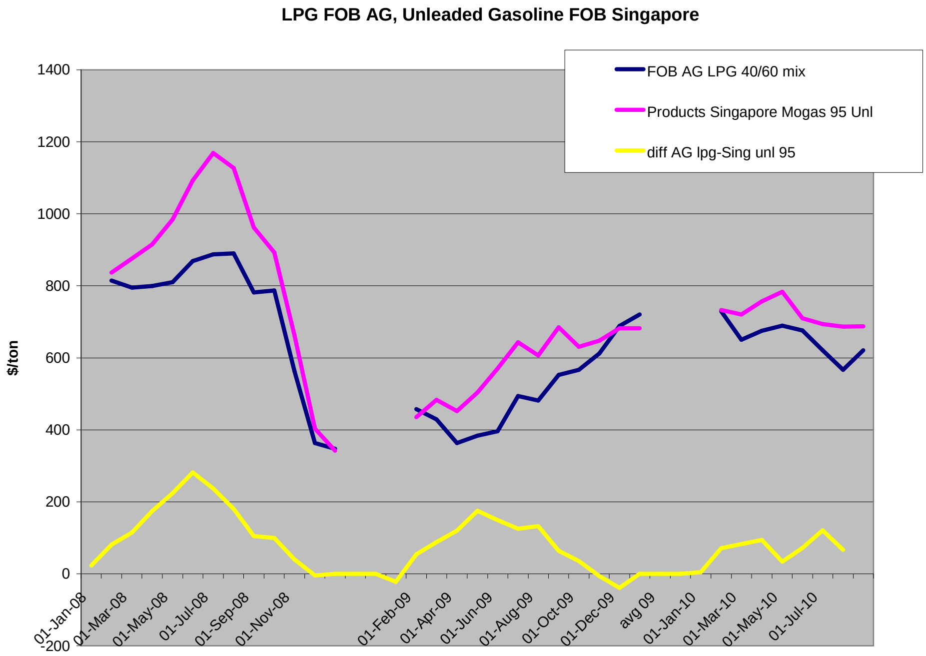
1.9.3 LPG Imports

LPG is produced in Bangladesh by ERL (13,000-15,000 ton/year) and Petrobangla facilities (5,000-7000 ton/year) and used for bottling and used as cooking fuel. It is also imported by a number of private companies to supplement the locally produced LPG to meet overall demand currently 80.000 tons/year. (BPC and Private Suppliers).

Private companies have built their own terminals and bottling plants and supply now the majority of the demanded LPG.

LPG can be used as an automotive fuel and is as such a replacement for CNG and Gasoline in cars beside its current use as cooking fuel. LPG tanks are different from CNG, but generally equal in size but designed to hold less pressure. LPG international market prices vary but are in general well below Fob Singapore Gasoline prices.

The yellow line is the price difference over the past 3 years between FOB AG for LPG and FOB Singapore Unleaded 95 RON Gasoline, and is approx 100 USD/ton over that period.



LPG receiving terminals are not expensive to build in comparison with LNG and in general consist of pressurised tanks, either as a sphere or as horizontal vessels called bullets. As an indication only; a LPG terminal capable to supply 20.000 tons per year would cost less than 10 million USD to build, excluding jetty facilities to receive sea tankers, but including a small loading rack for LPG trucks.

Cars that now run on gasoline or CNG can also use LPG without major modifications to the engine.

Conclusion LPG Imports

LPG seems only a natural competitor and possible substitute for the now used CNG adaption in cars and is fully compatible with Gasoline for use in cars. With the relatively low investment costs for a terminal this route will be attractive for study in more details.

Cost of LPG is considerably below other car fuels like gasoline and compared with Singapore Premium Gasoline well over 100 USD/ton cheaper.

LPG use is per km driven approx 1.15 times the equivalent use of Gasoline which will still leave a great incentive for LPG use.

1.10 Widening the crude oil base slate with more suitable crudes

Crude oil can come in many different gravities (API), and can differ greatly in its composition.

There are four main types of hydrocarbons found in crude oil, in varying amounts depending on the oil. Around half of the hydrocarbons in most crude oil are naphthenic, one-third is paraffin's, one-sixth is aromatics, and the rest are asphaltic. The colour can range from pure black or dark brown to greenish or yellowish, depending on the composition. Crude oil is often termed light, medium and heavy depending on density (^{0}API).

Additionally, crude oil is classified as sweet if it has very little sulphur, usually below 1% , and is classified as sour if it has a great deal of sulphur above 2.5 %. So a crude oil will usually be called something like a sweet, light oil, or a sour, heavy oil. Sweeter oils are more valuable than sour oils, because most countries have sulphur regulations for environmental reasons, and sweet oils require less treatment to remove the sulphur.

Light oils are more valuable than heavy oils, because more gasoline and diesel can be produced from a barrel of crude. Different regions on earth tend to have different types of oil, so crude oil is often classified based on where it comes from. Certain regions will act as a sample of a broader region, since they are seen as relatively representative of that broad region. For example, Dubai-Oman oil is a sour crude oil, and is used to benchmark most sour crude from the Middle East and Asia; West Texas Intermediate is a sweet, light oil and is benchmark for US, South American region; Brent for European, African and Mediterranean crudes.

For this study the relevance of different type of crudes is their impact on the Crude Distillation yield compared with other crudes and also the purchase price and the refiner's margin for each crude oil.

It is impossible to review all crude oils so besides ERL's used crudes (Arab Light, Murban and Gas condensate), the study will look only at Forcados (Nigeria) as a typical example of a very low sulphur and high distillate crude oil and Al Shaheen (Qatar), as example for a good quality and cheap heavy high sulphur crude with still good amounts of distillates.

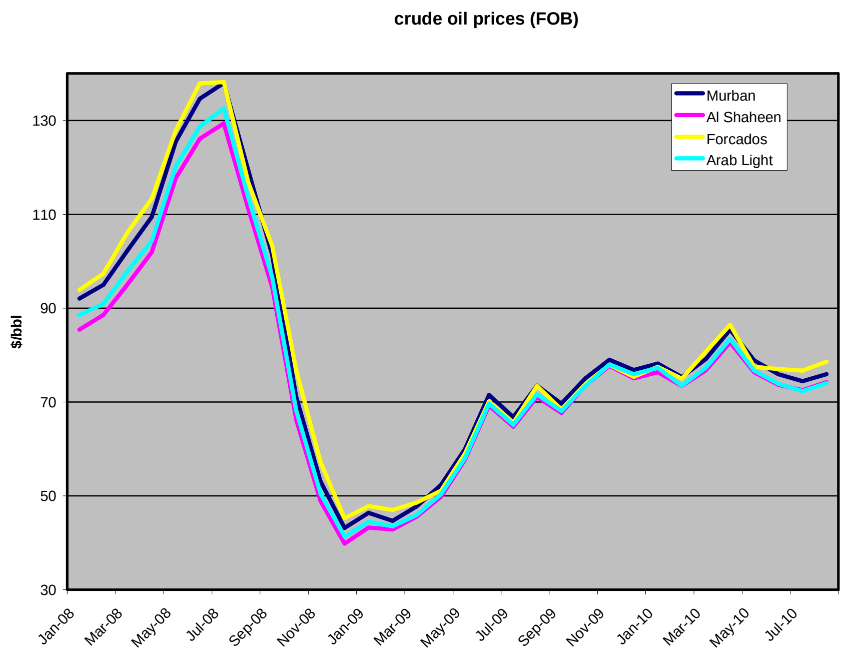
Overview of Crude oil Prices (FOB) of all relevant crude oils in this study:

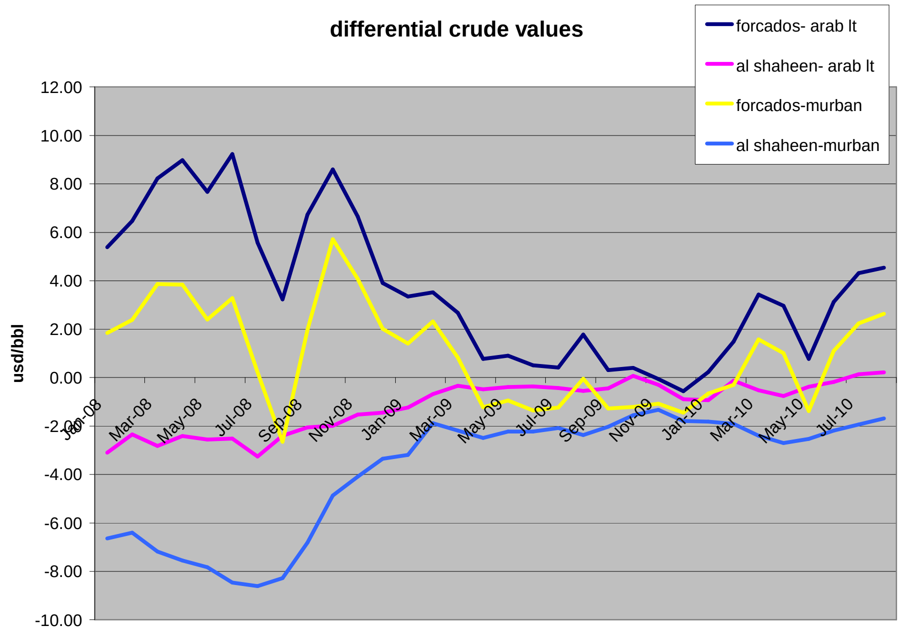
Crude prices are very volatile and had varied from 40 $/barrel to 140 $/barrel in just a time span of 3 years. The different Crude types differ between each other in relative minor amounts, as is visible in the second graph.

These value differences are primarily set by the market participants in professional crude oil price negotiations and spot- or term agreements.

In general price differentials between crude oils reflect the yield capabilities; % residue and % light products for each crude compared with others, and therefore a more expensive crude oil will usually produce a higher yield value in a simple crude distillation refinery.

Source: Platts Crudemarketwire.





N.B All crude oil prices and values are basis FOB load port.

Conclusion On Crude Oil Choice

Different crude oils will give different production yields. Costs differences are usually justified by the differences in value of the output of refined products.

Crude oil optimisation is a vital element in most refiners' mode of operation for their supply of oil products to markets. It will require a hands-on trading approach and well educated planning staff beside professional oil trading methods.

2. Analysis and detail Description of the Scenario's

2.1 Scenario 1: Base Case

2.1.1 Current ERL Configuration and Purchase of Refined Products

Brief description

In this base case first scenario ERL refinery is not modernised at all and continues to operate as it has done over the past years. This means that all deficit products to the full 6.0 million ton/year product demand will be purchased from Arabian Gulf and other refineries, shipped into Chittagong on small 25.000 ton product vessels that just meet the 9.0 m harbour draft.

This scenario is a reality if Bangladesh decides to accept the current oil product supply situation as acceptable and is not prepared to invest in refinery capacity.

Refinery configuration and operation

This scenario will use the actual current ERL refinery as it has operated over the past years. The production yield and crude oil runs are all actual and were also used in the refinery assessment report.

No adjustments for the observed conservative mode of operation as described in the assessment report.

Operating Units and Capacities:	
Crude Distillation Unit	33.000 bbl/day
Vacuum Distillation Unit	4.000 bbl/day
Platformer	1.700 bbl/day
Visbreaker	10.500 bbl/day
Merox units (LPG,Naphtha, Kero)	250.000 ton/year
Bitumen Blowing Unit.	70.000 ton/year

2.1.2 Supply and Demand Balance

In Scenario 1 there will be the current ERL production to meet the target future demand of 6.000.000 ton per year. With on average an actual ERL production of 1.275.000 tons per year this means that oil product importation is necessary and to be considered very high at 4.750.000 tons per year.

In this scenario ERL only provides for 21 % of the products demanded.

There is also a major imbalance in the oil product importation yield, as was already pointed out in the assessment, which is still by over 75% driven by Distillates, Kero and Diesel.

Also there is now an import of Furnace fuel oil as a result of the in the basic demand scenario increased need for oil fired power generation.

Demand imbalance and outright deficit will not only have an impact on the refinery operation and the storage facilities involved, but will require a professional approach to the oil trading/ purchase activities required if all 4.7 million ton will have to be brought into Bangladesh.

This is a realistic scenario if nothing will be done about the refinery situation. It will lead to ever more importation of products with increased pressure on importation facilities and of course the Supply Department to organise these supplies. On average products imports reach almost 13.000 tons per day which is unprecedented and likely not realistic.

Bangladesh supply and demand					Scenario 1		
In Kton	Petroleum product Demand		Refinery output		Product Import (neg =export)		Import per day
LPG	50,0	0,8%	13,0	1,0%	37,0	0,8%	0,1
Naphtha			83,7	6,6%	-83,7	-1,8%	-0,2
Premium	125,0	2,1%	37,1	2,9%	87,9	1,9%	0,2
Regular	125,0	2,1%	75,3	5,9%	49,7	1,1%	0,1
Spirits	10,0	0,2%	6,7	0,5%	3,3	0,1%	0,0
Kero	300,0	5,0%	295,0	23,1%	5,0	0,1%	0,0
Jet Fuel	350,0	5,8%	3,3	0,3%	346,7	7,3%	0,9
Diesel	3 500,0	58,3%	346,3	27,2%	3153,7	66,7%	8,6
Jute/other oil	50,0	0,8%	17,4	1,4%	32,6	0,7%	0,1
Furnace oil	1 370,0	22,8%	307,9	24,1%	1062,1	22,5%	2,9
Lubricants (import)	20,0	0,3%	0,0	0,0%	20,0	0,4%	0,1
Bitumen	100,0	1,7%	51,8	4,1%	48,2	1,0%	0,1
Refinery own used Fuel			37,5	2,9%	-37,5	-0,8%	
TOTAL	**6 000,0**	**100,2%**	**1 275,0**	**100,0%**	**4 725,0**	**100,0%**	**12,9**
Murban			555,9	43,6%			
Arab Light			610,7	47,9%			
NGCondensate			108,4	8,5%			
Crude Oil			1 275,0	100,0%	1 275,0		3,5
Crude+Products					6 000,0		16,4

In this scenario there is just the small quantity of Light Naphtha that is being exported to the nearest market which is Singapore and predominantly chemical industry. Sale Prices (fob ERL) are based on Platts Fob Singapore Naphtha less a small discount for freight.

2.1.3 Limitations to scenario 1

Chittagong Port capacity

All these imports, if evenly spread over each day, will require a daily discharge of 16.400 tons for both oil products and crude oil at the main Jetties 6 and 7.

Discharge capacity is approx 1400 cubic meters per hour at the crude oil and product jetties, and therefore product and crude imports will require 14-16 hours discharge from moored vessels into ERL refinery and MI product tanks each day. It is also assumed that approach to and from the harbour is possible 24 hours per day (currently not possible as per CPA rule) and that there is no hold up in the arrival and mooring of all vessels.

Alternative is to extend the capability at jetties 6 and 7 to accommodate 2 vessels at the time if the port is only operated at daylight hours. This will require a second loading arm and mooring extension of the jetties.

In addition there will now be imports of Heavy Fuel oil for use in power and electricity generation which can only be received via a "dark line" system and therefore will have to use the crude oil discharge facilities.

The combined use for import of crude and fuel oil will put a limitation on jetty 7 alone where now on average extra Fuel oil discharge of 3.000 ton has to be accommodated beside the 3.500 ton average current daily crude reception. Time also will be lost as each shipment will require mooring time and disconnection plus sailing away time.

Chittagong three Main Marketing Installations (MI) are the main distribution points for shipments out to all the other terminals or depots in Bangladesh. It is assumed that the loading of all the deliveries to the deports with small inland tanker can be served from the remaining jetties 3, 4, (pontoon) and 5 (fixed) and all other smaller vessel handling jetties.

However there will be no evenly arrival of vessels and the sailing time to and from the jetties is also depending on the tidal movements and consequently the use of discharge time plus movements to and from Chittagong harbour will approach a continuous required 24 hours on daily basis, which is unsustainable on a daily basis.

Chittagong Port Authority (CPA) when asked does not support vessel activity on a 24 hour basis and closes the port at night time, thereby reducing the overall port capacity to half or less. Only vessels are allowed in and out of port during daytime hours and effectively severely limiting oil movement capacity.

CPA is concerned about increased and unsustainable congestion in the port if imported volumes increase above current import levels of 10.000 ton/day (crude oil+product imports total of 4.0 million tons). This means that with all other (non oil) traffic Chittagong may be close to full capacity and further product imports becoming difficult to accommodate.

CPA would encourage therefore a new much larger refinery to be built at a different location as a second potential to be created seaport near Kutubdia and/ or Sonadia.

Direct import of purchased product to other ports

This option is not realistic.

Draft at all other Bangladesh ports is well below the Chittagong draft which is already very shallow at 9 meter draft maximum and can just accept smaller product vessels of max 25000 ton size. It is neither efficient nor feasible to ship from AG or Singapore in small sea going coasters or barges given the distance that needs to be travelled at high seas. The port of Mongla draft is 6.2 meters and could at high tide probably accept vessels with a 10-15.000 ton cargo maximum, but these vessels would be very expensive to charter and they can't service all the way from the distant load port and across high seas.

Also port dimensions limitations like LOA (length overall) and beam will restrict the oil tankers size and capability to discharge even further.

Product vessel chartering capacity

For Scenario 1, if all product imports are bought FOB, the shipping required would be a daily charter of 13.000 tons vessel capacity or more realistic a 25000 ton vessel every 2 days. This means that BPC and its agent BSC will have to enter the market almost on a daily basis for its transportation needs.

This is possible, but will require an active team of chartering professionals who would have to work very close with the receiving jetty and terminal personnel to prevent congestion and delays in discharge.

It is vital that vessels are chartered either by the supplier or BSC that do not need any lightering, but to approach the port for direct discharge of the entire cargo.

Another limitation would come from international pressure on load port countries and of course then also Bangladesh to accept and charter only ships with double hull, like is the norm now in Europe, USA, and most developed Asian countries.

Storage and pumping capacity

In the assumption on storage capacity (9) the total available storage is taken into account regardless of ownership.

Summarised ERL and the MI have a total main product storage gross capacity (see assessment report) in Chittagong ad followed:

In 000 CBM	Crude	Products
ERL	302.5	268.5
MI		304.3
Total	302.5	572.8

Storage at ERL and MI has been analysed in great detail in the refinery assessment, and included a benchmark utilisation.

For the combined storage capacity at Chittagong the assumption of a 12 times year utilisation, or a full in out per month is a conservative approach. This effectively means for every month a tank is filled and emptied.

Many refineries have turnarounds of 24 times per year, and even higher.

With an utilisation factor of 12* tank in out rotations per year the ERL+ MI tanks can handle 6.9 million tons of product per year, and thus can operate the 6.0 million ton/year product demand without the immediate requirement for new build capacity. Possibly some lines and use of tank classification may have to be changed or relocated but no major investment in storage tank capacity is needed.

Jetties and pumping capacity will need improvement. As discussed earlier the port and jetty capacity is at maximum in this product importation scenario. Pumps at the jetties or at the MI will control the vessel discharge and they should be capable to pump 3000 cbm per hour instead of the current 1400 cbm/hr. Not only will the discharge of vessels go twice as fast, and thus double the mooring capacity per day, but also the cost of demurrage per vessel will be less.

A small 20-25.000 ton product tanker should be in and out of the port within 15 hours (including required port approach time and all fast to mooring point hours) which will be necessary to accept the required on average 13.000 ton daily product deliveries and similar volume shipments out to depots in this Scenario 1.

A bigger pump or additional booster pumps needs to be installed to the concrete jetties no 6 and 7 as a minimum to achieve rates of 3000 cbm/hour, but further pumping and mooring capacity addition on other jetties will improve the amount of vessel traffic in the harbour, including the barge and depot vessels shipments out of the MI to the depots elsewhere in Bangladesh.

2.1.4 Crude Oil Choice for this Scenario1

Since this scenario is based on actual average 10 year ERL performance the crudes base slate are those actually processed: Murban, Arab Light and Nat Gas Condensates.

2.1.5 Product Qualities Scenario 1

Due to the much larger import volumes in Diesel and Fuel Oil but with the same refinery production the main qualities (sulphur) will improve as imported product is of much better standards than ERL current output. The overall improvement is thus solely due to better quality importation from AG refineries where most of the EU specification (for Diesel and Jet Fuel) and US gasoline specs are the norm.

With ERL output of only 21 % of the demand and 79% being (Distillate oriented) imports the average quality will greatly improve after blending the relative small and low quality refinery product output with the high quality purchased imports in the MI and ERL tanks.

Key product test specifications

		ERL actual situation	Scenario 1	Target
Light Naphtha				
Paraffins	%vol	85	unchanged	
Doctor test		Positive		
Lead	ppb	8		
Vapour Pressure	KPa	84		
Gasolines unleaded				
Octane Research		95	unchanged	
Benzene	% wt	5		1
Sulphur	ppm	250		100
Oxygenates	%wt	NA		
Aromatics	%wt	NA		
FBP	C	210		
Vapour Pressure	KPa	85		
Jet Fuel A1				
Defstan 91-91**		no production	no production	production
Kerosine household				
Distillation IBP	C	160	unchanged	
Smoke point	mm	20		
Flash point	C	40		
Sulphur	ppm	2850		350
Diesel				
Cetane Index		50	unchanged	
Sulphur	ppm	2800	750	350
Cloudpoint	C	NA		
Flashpoint	C	39	50	55
Furnace Oil				
Sulphur	%wt	3.5	3.3	3.0

2.1.6 Efficiencies in Scenario 1

As all operating units and utilities are based on actual ERL operations there is no efficiency gain or loss, other than the existing inefficiencies described in the assessment;

- Conventional electricity and steam generation with 32 % efficiencies.
- Some loss of power and heat due to the outdated technology.
- Loss of gases to stack and open air.

2.1.7 Economics of Scenario 1

As was done in the assessment, each Scenario will have its own profit and loss estimate which is based on calculated yields and Platt's prices (see assumptions).

The supply of the total demand of 6 million ton/year will differ as refinery volume and yield will change in each scenario. There is a refinery margin result per scenario.

The imbalance of refinery production and total demand is the imported volume, which is purchased and will get its own trading result.

REFINERY RESULTS	**Scenario 1**			**USD/ton**
		Refinery output		**Platts Sing basis**
		Kton	**%**	**2007-2010**
LPG		13.0	1.0%	657.44
Naphtha		83.7	6.6%	652.06
Premium		37.1	2.9%	720.26
Regular		75.3	5.9%	713.92
Spirits		6.7	0.5%	667.06
Kero		295.0	23.1%	735.46
Jet Fuel		3.3	0.3%	735.46
Diesel		346.3	27.2%	695.10
Jute/other oil		17.4	1.4%	685.10
Furnace oil		307.9	24.1%	438.00
Lubricants (import)		0.0	0.0%	920.00
Bitumen		51.8	4.1%	488.00
Refinery own used Fuel		37.5	2.9%	
TOTAL Product value		1,275.0	100.0%	611.95
Murban		555.9	43.6%	611.44
Arab Light		610.7	47.9%	565.22
NGCondensate		108.4	8.5%	617.06
TOTAL Crude Oil costs		1,275.0	100.0%	589.78
Freight costs				13.00
Lightering				5.00
Refiners margin Gross				4.17
Refinery Operating expenses				8.97
Net refiners margin	**$/ton**			-4.80
Net refiners margin	**$/bbl**			-0.65
Total import cost crude	**mln USD**			**774.9**
Total profit/loss on refining	**mln USD**			**-6.1**

Note: the Scenario 1 refiner's margin is just slightly negative (-0.65 USD/barrel) as it was the case with the actual refinery margin in the assessment. The observed period is January 2008 to August 2010, the same period and therefore the same pricing data as in the assessments.

The second part of the Scenario analysis is the Trading results of all product purchases, bought at AG refiners at Platts Fob AG, shipped to Bangladesh for average 22.50 USD/ton and sold domestically at the market import party price (Platts FOB Singapore).

TRADING RESULTS	Scenario 1	Imports (- export)		USD/ton Purchase Cost AG Platts — Platts AG Arab Gulf	USD/ton Revenue import parity — Platts Sing basis
		Kton	%	2007-2010	2007-2010
LPG		37.0	0.8%	627.44	657.44
Naphtha		-83.7	-1.8%	654.65	652.06
Premium		87.9	1.9%	697.15	720.26
Regular		49.7	1.1%	691.05	713.92
Spirits		3.3	0.1%	669.65	667.06
Kero		5.0	0.1%	714.57	735.46
Jet Fuel		346.7	7.3%	714.57	735.46
Diesel		3153.7	66.7%	681.90	695.10
Jute/other oil		32.6	0.7%	671.90	685.10
Furnace oil		1062.1	22.5%	422.48	438.00
Lubricants (import)		20.0	0.4%	920.00	920.00
Bitumen		48.2	1.0%	472.48	488.00
		-37.5	-0.8%		
TOTAL		4725.0	100.0%	630.66	645.71
Freight costs				22.50	
Lightering				0.00	
Trading margin Gross				-7.45	
Operating expenses	estimated			1.00	
Net trading margin		$/ton		**-8.45**	
Net trading margin		$/bbl		**-1.14**	
Total import cost products		mln USD			**3086.2**
Total profit/loss on trading		mln USD			**-39.9**

Note: The refinery product output volume and the import volume add up to 6.0 million tons/year.

The revenue side is Platts FOB Singapore; the market parity level for Bangladesh proposed domestic price. The cost side is Platts FOB Arab Gulf and 22.50 USD/ton freight.

Overall result for this Scenario 1:	In USD per Year
loss on refining	-6.1 million
loss on importation	-39.9 million
Total loss for Scenario 1	-46.0 million

2.1.8 Required investments for Scenario 1.

Scenario 1 is the actual situation with regard to ERL current operation and in the refinery there are no or hardly any investments. Since the volume of imported product rises and in light of the under 3 described port logistic limitations there will be minor investments required to accommodate the increased flow of imported products.

All costs are estimates based on similar projects elsewhere

	In USD
Pump capacity to 3000 cbm/hr at Jetties RM 6 and 7	0.6 million USD
Extension to RM 6+7 loading arms + mooring space If no 24 hour service	2.0 million USD
Total investment for Scenario 1	2.6 million

2.1.9 Scenario 1: financial result over a 10 year period

Not surprisingly this Scenario is financially quite disappointing. The assumptions of prices, yields and imports, and the Platts Singapore FOB Platts quotations as the Bangladesh import parity price are applied in this Scenario.

It reflects the non sustainability of the current BPC situation; the ERL refinery operation, and the practice to meet demand with the expensive finished product imports.

The result is a 350 million USD loss over a 10 year period presented as a Net Present Value in today's money, and for a relative small operation of 6 million ton per year this means on average a loss of almost 6 USD per ton domestically sold product.

Net present value/ IRR		Scenario 1									
interest rate	5.5%										
effective period	year	now	2	3	4	5	6	7	8	9	10
Investments	mln USD	-2.6									
refiners margin	mln USD	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1
trading margin	mln USD	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9
total margin	mln USD	-48.6	-46	-46	-46	-46	-46	-46	-46	-46	-46
NPV	mln USD	-$349.2									
IRR		NA									

Note: all calculations were done on basis of Market Parity; Platts Singapore FOB. Any level of final consumer sales prices below the market parity; will further deteriorate the bottom line results for BPC and will end in a receivership if it was a private company. The result is this very high negative Net Present Value of 350 million USD over a 10 year period.

Subsidies given to the general public and other discounted pricing practices are not only adding to further losses but also create a false signal to increase consumption far beyond sensible economic laws of supply and demand. More about internal pricing and subsidies will be discussed in the Policy recommendations.

2.1.10 Pro/strengths and contra/weaknesses of Scenario1

The only major difference between the current oil supply situation in Bangladesh and this Scenario1 is the demanded volumes and the emphasis on increased product purchases and trading programs to meet that demand.

Pro and strengths

- Minimal or no investment required
- Overall inland product quality improved due to scale of good quality specification imports.
- Adaptation and professionalization of the 'Supply and Trading' organisation.
- No massive construction and other building activity.
- Existing storage facilities utilised at higher throughput.
- Scenario assumes implementation of international market price as basis for domestic prices.

Contra and weakness

- Probably unrealistic to expect all oil product vessel movements to be feasible in Chittagong.

- Port is daytime service only with CPA not inclined to accept 24 hour opening this will give congestion and delays for all in/out movement.
- Refinery operation result is 6.1 million $/year loss (-0.65 $/bbl), product purchase activity another 39.9 million $/year loss, total (for benchmark purpose) 46 million $/loss per year.
- Port draft remains a major obstacle to an efficient crude oil direct discharge.
- Other ports are not capable to import even the smallest product vessels.
- Chartering costs at 4.7 million ton product imports will be enormous.
- No new technology in refinery and no change in utility in efficiency and reliability.
- No supply flexibility with the refinery only producing 21 % of the demanded products and demand yield remains distillate oriented.
- Dependency on foreign product import is (too) high.
- Working capital requirements are high with most product purchases to be paid within 1 week of shipment.

2.2 Scenario 2: Low investment Case aimed to return to positive refiners margins

2.2.1 Moderate Improvement of the existing ERL Refinery

Brief description:

Basis is the existing ERL refinery operation, but with possibly new (distillate rich) crude oils in the crude oil feedstock slate, like Forcados, Nat Gas condensate.

Scenario 2 is focussed on ways to initially increase in Distillate output and better operating efficiencies, **without major investment in new facilities and thus no substantial increase in production capacities.**

There will be minor investments in debottlenecking of the Crude oil distillation unit, the reactivation of Hydrodesulphurisation unit and a small improvement in the Vacuum unit.

Mode of operation is changed to achieve much higher Octane from the Platformer, and the Hydrogen gas from the process will be used in the Diesel desulphurisation.

The refinery will produce Premium Gasoline's (HBOC) and will also produce Jet Fuel and less household Kero.

The refineries Diesel output will be much better in quality and have a sulphur content of 500 ppm with also better driving properties due to the reinstated Hydrodesulphurisation unit.

The Visbreaker will receive slightly better quality feedstock due to a deeper cut atmospheric residue from the Crude oil unit and some vacuum residue and will produce some more distillate than under the current very low severity thermal cracking operation of paraffinic atmospheric residues.

Sulphur content in the Furnace Oil will be lower as there is the introduction of low sulphur, high distillate yielding crudes (Forcados) in the base slate.

The refinery Crude Unit operation is assumed to be capable to reach 36000 barrel/day with minor modifications from the 33000 barrel/day in the base case scenario 1 and will also stay longer in operation during a year with less shutdown days. Condensates can be spiked into the crude oil feed to approx 10 % maximum.

Utility efficiency and reliability is increased by the investment in a small 8 MW/h Combined Heat and Power gas turbine and shutting the less efficient conventional steam boilers.

This Scenario 2 will not have a substantial change in the amount of imported products as described in Scenario 1 however. There will still be large product imports although it is 325.000 tons less than in Scenario 1 due to the higher throughput and changed mode of operation in the refinery.

The main purpose of this Scenario 2 is to show that ERL's refiners margin can be improved with widening the potential crude oil base slate, and operate some of the units differently, maybe less conservative, with a minor increase in overall capacity.

Some efficiencies will be achieved by using a small CHP unit for electricity and heat supply.

Also the trading and product purchase program will result in less expensive purchases and fewer losses as the refinery will produce a major portion of its own Jet Fuel and higher octane premium gasoline's.

2.2.2 Refinery Configuration and Operation

CDU

This scenario 2 will use the existing ERL refinery and will modify the CDU and Vacuum unit. The production yield will maximise distillates but will produce 2 Kero types, SKO and Jet Fuel.

Crude oil runs are increased from current 1.3 million ton/year to 1.6 million ton/year. This increase is the result of a debottlenecking of the crude units overhead section, increasing cooling and reflux drum capacity, Increase in the Kero and diesel strippers flow rate and possible addition of one or two draw off trays in the upper part of the rectifier (Kero and Diesel fractions) to allow a higher distillate volume to be drawn off.

The lowest temperature boiling liquids; LPG's and light Naphtha's produced in the preflash fractionator will be routed directly to the Naphtha stabiliser instead of current flow back into the top of the main fractionator. This will relieve the main fractionation and will allow more barrels of heavier oil to be refined in combination with the other modifications and thereby freeing up overhead distillation capacity and cooling/reflux flow capacity.

Part of that freed capacity will then be used to accommodate the very light Natural Gas Condensates as part of the overall base slate.

In combination with less rich Light Naphtha type crude oils, such as Murban and partly replaced by naphtha poor and distillate rich Forcados and as a consequence the total slate is using less overhead capacity . Increase of the main furnace inlet temperature to 370 degree C will produce some more distillate.

There is then extra capacity to refine the Natural Gas Condensates (NGC), which consists mainly of Light Naphtha for export and as low octane gasoline component and the NGC needs to be blended or spiked in the main crude oil base slate instead of the current distillation method using the unsuitable desulphurisation fractionator.

Vacuum Distillation Unit (VDU)

The Vacuum unit design does not allow a additional capacity by debottlenecking of pumps and ejector system due to the original design as feedstock preparatory unit for the Bitumen production.

With the introduction of more distillate rich crudes such as Forcados the Vacuum Unit with minor modification in the Ejector and condenser will be able to produce some extra light vacuum gasoil which is similar in quality as the heavy atmospheric Gasoil from the CDU.

The Platformer

The Platformer unit will be operated in this Scenario at a higher severity operation to produce 99-100 RON Platformate, allowing the own production of unleaded 95 RON premium gasoline. For this only minor modifications to the unit are required unless the basic design is not supportive of higher pressures to 45-50 kg/cm2. The catalyst activity life, which today at low severity is over one year, will require in the new mode a 14 day regeneration every 7 to 9 months. Part of this extra capacity loss is reflected in the higher operating costs as production days lost.

The sulphur and aromatics (benzene) qualities of the MS and HOBC gasoline's will not change as no investment is done in aromatics and sulphur removal in this scenario.

The Mild Hydrocracker

The now shutdown converted Mild Hydro cracking unit will return to active service as a desulphurisation unit for which it was originally designed. The unit's purpose and mode of operation is:

- To desulphurise and stabilise and hydrogenate the Visbreaker Distillates.

- To desulphurise and hydrogenate the light Vacuum Gasoil.
- To reduce the overall sulphur in the ERL Diesel pool.

Not all volumes can be processed as the unit is very small, and debottlenecking not expected to produce extra capacity.

It is likely that no major investments will be required to reinstate the unit. A thorough routine maintenance and replacement of valves and seals, possibly some compressor parts may be sufficient together with fresh catalyst in the existing desulphuriser's reactor.

The required hydrogen will be supplied from the Platformer and this is more than sufficient for the required Hydrogen consumption in the reactors.

The unit will operate at minimum 30 kg/cm2 to achieve its desulphurisation target of 1000 ppm. (0.1%) and should be operated at 50 kg/cm2 to achieve 500 ppm sulphur (0.05%), subject to the original design pressure tolerance.

The Visbreaker

No major changes in the operation, except that part of the feed will be a low sulphur long residue from Forcados crude which will reduce the overall sulphur content in the Furnace oil pool. Also since these low sulphur crudes are somewhat more aromatic than Murban, the Visbreaker severity could be increased to yield a better gasoil conversion. This effect is not accounted for in this Scenario however.

Power Generation

Utility improvement is justified by a better reliability. In the assessment conventional power and electricity generation achieved just over 32% efficiency. The 2 main conventional fired 3 MW steam turbine units are now the main suppliers to the refinery power system.

With the Hydrodesulphurisation back on line and higher and more efficient CDU/VDU throughput the refinery power requirement will increase.

Introduced in this Scenario is a modern 8 (2 units of 4) MW Combined Heat and Power technology Gas turbine unit, fired on purchased natural and even refinery gases. The efficiency of such CHP unit is on average 75%, more than double the current conventional boilers, if maintained at constant speed and properly maintained.

Beside reliability there is the efficiency gains, which will be reflected in the lower refinery consumption and loss and thus lower operating costs, and will require considerable less, over half of current volumes of gas purchase. The CHP will also provide all medium pressure process steam requirements in the CHP process.

Operating Units and Capacities:	
Crude Distillation Unit	36.000 bbl/day
Vacuum Distillation Unit	5.000 bbl/day
Platformer	1.700 bbl/day
Hydrodesulphurisation Unit	1.700 bbl/day
Visbreaker	10.500 bbl/day
Merox units (LPG,Naphtha, Kero)	250.000 ton/year
Bitumen Blowing Unit	70.000 ton/year
CHP unit	8 MW/h

2.2.3 Supply and Demand Balance

In Scenario 2 there will be the improved ERL production to meet the target future demand of 6.000.000 ton per year. With on average an actual ERL production of 1.600.000 tons per year this will still require oil product importation at 4.400.000 tons per year.

In this scenario 2 ERL provides for 27 % of the products demanded already an improvement of 6% compared to scenario 1.

There is less of the major imbalance in the oil product importation yield, as was already pointed out in scenario 1 and the assessment, which is now just 75% and remains driven by Distillates, Kero and Diesel. There is the import of Furnace fuel oil as a result of the in the basic demand scenario increased need for oil fired power generation. Jet fuel is partly produced now by ERL so (expensive) imports are more than halved, and the same applies to ERL now producing a major portion of the previously imported HOBC gasoline.

Since Jet Fuel and 95 Unleaded are among the most expensive products previously all purchased the trading results will improve as well beside the refinery own refiners margin.

There is however still a considerable demand imbalance and a 4.4 million ton/year outright product deficit.

Product Imports per day is on average 12100 tons of product and thus very high although slightly down from the 12.900 ton day in Scenario 1.

There is the exported Light Naphtha volume, which remains without purpose in Bangladesh as there is no petrochemical industry, nor use in for example the introduction of an Isomerisation plant in this Scenario.

Bangladesh supply and demand					Scenario 2		
In Kton	Petroleum product Demand		Refinery output		Product Import (neg =export)		Import per day
LPG	50,0	0,8%	17,3	1,1%	32,7	0,7%	0,1
Naphtha			81,6	5,1%	-81,6	-1,9%	-0,2
Premium	125,0	2,1%	52,1	3,3%	72,9	1,7%	0,2
Regular	125,0	2,1%	74,4	4,6%	50,6	1,2%	0,1
Spirits	10,0	0,2%	19,0	1,2%	-9,0	-0,2%	0,0
Kero	300,0	5,0%	154,1	9,6%	145,9	3,3%	0,4
Jet Fuel	350,0	5,8%	210,0	13,1%	140,0	3,2%	0,4
Diesel	3 500,0	58,3%	494,3	30,9%	3005,7	68,3%	8,2
Jute/other oil	50,0	0,8%	25,8	1,6%	24,2	0,5%	0,1
Furnace oil	1 370,0	22,8%	384,0	24,0%	986,0	22,4%	2,7
Lubricants (import)	20,0	0,3%	0,0	0,0%	20,0	0,5%	0,1
Bitumen	100,0	1,7%	62,7	3,9%	37,3	0,8%	0,1
Refinery own used Fuel			25,2	1,6%	-25,2	-0,6%	
TOTAL	**6 000,0**	**100%**	**1 600,4**	**100,0%**	**4 399,6**	**100,0%**	**12,1**
Murban			297,4	18,6%			
Arab Light			766,7	47,9%			
NGCondensate			136,1	8,5%			
Forcados			400,2	25,0%			
Crude Oil			1 600,4	100,0%	1 600,4		4,4
Crude+Products					6 000,0		16,4

This is a realistic scenario if there is only interest for minor but key investments. If these are made and a different operating attitude is implemented in the current ERL refinery operation the financial Profit/Loss impact is considerable.

It will not lead to a significant increase in refinery capacity and no reduction of importation of products but will make Bangladesh less dependent on expensive Jet Fuel and good quality high RON gasolines.

The overall refiner's margin will improve significantly with just minor effort.

Refinery margins that are positive will prove the refinery to have a sustainable longer term right to operate, and will return cash flow to reinvest and maintain margin improvement.

2.2.4 Limitations to Scenario 2

The same limitations as discussed under Scenario 1 in detail are applicable to this Scenario 2, as the number and purchase tonnage of small product vessel movement required is not that different from Scenario 1.

Therefore it will be sufficient to summarise the limits here:

Port capacity

- Port unlikely to be able to receive all products without major changes.
- Port to be open on 24 hour basis.
- Jetty 6 and 7 pumping and mooring capacities insufficient for all discharges.
- Addition of one extra mooring position at extended jetty 6 and/ or 7 is required.
- Waiting times and demurrage costs will increase causing general congestion in the port.
- Heavy Furnace fuel oil will have to be discharged at the crude oil jetty to preserve the clean discharge systems.
- Small inland tanker and barge movements to depots have to take place from all remaining jetties and will also increase congestion there.
- Other potential ports for product imports are not available nor realistic due to very shallow draft of 6-7 meters which does not permit even the smallest product tankers.

Product vessel chartering capacity

- Almost every 2 days requires to charter 25.000 tons vessel capacity.
- Will require an active team of chartering professionals who would have to work very close with the receiving jetty and terminal personnel.
- International pressure from load port countries and of course then also for Bangladesh to accept and charter only ships with double hull, increasing the cost of transport..

Storage and pumping capacity

- ERL and the MI have a total main product storage gross capacity of 573000 cbm and 302000 cbm for crude oil and NatGas Condensate.
- With a utilisation factor of 12* per year ERL+ MI tanks should be able to handle 6.9 million tons of product per year.
- The 6.0 million ton/year product demand do not require new storage capacity.
- Possibly some lines and use of tank classification may have to be changed or relocated.
- Jetties and pumping capacity will need improvement. Capable to pump 3000 cbm per hour instead of the current 1400 cbm/hr.

- The currently used 20-25.000 ton product tankers should be in and out of the port within 15 hours (including required port approach time and all fast to mooring point hours)
- No lightering of product vessels. Direct approach required to prevent extra congestion.

2.2.5 Crude oil choice for this Scenario 2

ERL has been remarkably consistent to maintain year on year only a choice of 3 processed crude oils; Murban, Arab Light and Nat Gas Condensates. And perhaps in the far past an occasional other crude oil.

Crude oil, as explained in the introduction, can make a real difference in the quality of the production yield and of course the individual refiners margin that each crude will have when processed at the refinery.

Bangladesh demand is a distillate driven demand and there are crude oils available such as Nigerian produced Forcados that have a relative large quantity of distillates in the yield. This Scenario is introducing Forcados crude to vary and force the yield towards more Diesel generating yields and reducing Naphtha rich Murban crude instead.

Also Murban crude is relative expensive and while it is an easy supplied crude oil without problems for the refinery, BPC should be open to other crude oils, both from a refiners margin perspective and of course from the yield quality aspect of the crude oils observed.

To illustrate this point Forcados and Murban are compared in the table below. Striking difference is the yield for each and the (at actual Platts values) calculated gross refiners margins for each if individually run at ERL refinery in Scenario 2.

API	**30.6**	**39.6**	**Platts Sing**
	%wt	**%wt**	**$/ton**
	Forcados	Murban	
LPG	1.2%	1.3%	627
Naphtha	-0.3%	5.3%	652
Premium Gasoline HOBC	3.3%	3.4%	721
Regular Gasoline MS	4.7%	4.9%	714
Spirits	1.7%	0.7%	730
Kero	9.9%	12.2%	735
Jet Fuel	8.0%	13.8%	735
Diesel	45.2%	29.8%	695
Jute/other oil	0.0%	3.3%	680
Furnace oil	24.3%	23.1%	438
Bitumen	0.0%	0.0%	
Own cons/loss	2.1%	2.2%	
	100.0%	100.0%	
	$/bbl	**$/bbl**	
Refined value	87.00	82.69	
Crude oil cost Fob	81.30	80.36	
freight	3.00	2.00	
refiners gross margin	2.70	0.33	

The table clearly favours to run Forcados crude oil, despite the higher freight costs (approx 22 USD/ton) for loading at Nigeria and sailing via Cape of Good Hope to Chittagong. This does not mean that Forcados should be purchased. It is a mere indication of a crude oil that seems to fit in this distillate demand Scenario very well. There are many crude oils like Forcados..

Another interesting point is the much lower sulphur content in all from Forcados refined products compared with Murban products which are all much higher.

The outcome of introducing Forcados is also a reduction in refined product sulphur content and will require less desulphurisation efforts than without this crude oil substitution.

It is essential for every refinery to optimise between a list of acceptable crude oils and chose a crude oil base slate dictated by yield , sulphur balance and of course by economics.

Forcados can never be run for 100% of the crude oil feed. Because of its particular distillate yield which will cause a problem for the current ERL Crude Unit fractionation and also as it is not suitable crude for Bitumen production. In Scenario 2 the Forcados quantity is therefore limited to 25% of the total crude throughput.

All high distillate and low sulphur type crude oils should be relevant for the Bangladesh refinery supply.

This function is typically done by the Supply and Trading department and the refinery planning group.

2.2.6 Product qualities Scenario 2

The product qualities in this scenario will be slightly different and contain less sulphur as Forcados crude oil is a low sulphur crude.

However since the amount of imported products is still very high compared to the refinery production there will not be a major difference compared with the qualities analysis as presented in Scenario 1. Therefore summarised:

- The main qualities (sulphur) will improve as imported product is of much better standards than ERL current output. (Diesel sulphur quality at around 750 ppm after blending with imported Diesel)
- The overall improvement is due to the introduction of Forcados low sulphur crude and the reactivated small Hydrodesulphuriser unit.
- Better product quality importation from AG. Refineries where most of the EU specification (for Diesel and Jet Fuel) and US gasoline specs are the norm.

2.2.7 Efficiencies in Scenario 2

In Scenario 2 are some important efficiency improvements both in the refinery processing and the utilities.

Process Units. With the main fractionator bypass of Light Naphtha there will be less energy required in the main CDU furnace as less of the light products require distillation. Also an improved tray and stripper circulation in the mid distillate area will improve heating efficiencies. This is leading to a lower amount of Gas and Fuel oil being fired in the furnace.

With the introduction of 8 MW/h (installed as 2 units *4 MW/h) CHP gas turbine which will provide around 70-75% efficiency compared with the current conventional electricity and steam generation with only 32 % efficiencies. This simply means a resultant expense of more than halve of the costs to produce steam and electricity.

Thermal power systems such as gas turbines inevitably reject heat into the environment and the thermal efficiency of a heat engine cannot be 100%. This means that some of the heat released during combustion in a gas turbine is lost into the environment.

The thermal efficiency of conventional fired (steam) turbines varies from 20% to about 40%. Thus, 60% to 80% of the heat supplied into a steam turbine by burning of the fuel is wasted.

CHP systems also known as Cogeneration utilizes this waste heat to be used for heating requirements present in any refinery such as process steam resulting in an appreciable increase in the overall efficiency of the power and heating system.

The increase in overall efficiency of any CHP system with increasing heat to power ratio is remarkable. The overall efficiency in the region of 75% is possible with CHP resulting in a significant reduction in fuel and consequently operating costs. The reduction in fuel consumption inevitably results in a reduction in CO_2 emissions, which is thought to be responsible for global warming.

Hence, CHP systems are not only beneficial in reducing electricity and steam costs but they are also friendlier to the environment. Subsequently a CHP plant, of around 8MW electrical output, can reduce the amount of carbon dioxide emitted into the atmosphere by 18,000 tonnes per year. Carbon dioxide emissions are now restricted in many countries in a drive towards satisfying the Kyoto protocol.

In this Scenario and next ones, an overall CHP efficiency of 75 % is assumed which will reduce the investment cost compared with sophisticated CHP units that will give 90% efficiencies. Typical cost indication of an 8 MW/h electricity + 350 ton/day of medium pressure steam gas turbine CHP unit is 10-12 million USD. (Rolls Royce and Siemens)

2.2.8 Economics of Scenario 2

As was done in scenario 1, this scenario 2 setup will have its own profit and loss estimate for the refinery and the trading part, and is based on calculated yields and Platts prices (see assumptions).

Operating Expenses

The overall operating expenses rise from previous scenario and in the assessment used 8.97 $/ton to 10.50 $/ton in Scenario 2. This is due to the improvements in CHP and process unit energy efficiencies (a gain of 0.63 $/ton crude throughput) and it is offset by the increased cost of the Platformer (due to better octane number) and the reactivated Desulphurisation units mode of operation (extra 2.16 $/ton crude throughput)

There is the extra cost for regeneration of the Platformer catalyst, including the shutdown days and lost production, the operation of the Hydrodesulphuriser and the loss of one week Visbreaker shutdown for decoking of exchanger/furnace tubes.

Benefits are a much better efficiency for the CHP Gas turbine compared with the conventional fired steam generators costing less and reduction of Balkanabad gas to be purchased. The net effect is an extra operating cost is 1.53 USD/ton, but all produces a much more valuable yield and increased throughput.

Refinery Margin calculation

REFINERY RESULTS	Scenario 2			USD/ton
		Refinery output		Platts Sing basis
		Kton	%	2007-2010
LPG		17.3	1.1%	657.44
Naphtha		81.6	5.1%	652.06
Premium		52.1	3.3%	720.26
Regular		74.4	4.6%	713.92
Spirits		19.0	1.2%	667.06
Kero		154.1	9.6%	735.46
Jet Fuel		210.0	13.1%	735.46
Diesel		494.3	30.9%	695.10
Jute/other oil		25.8	1.6%	685.10
Furnace oil		384.0	24.0%	438.00
Lubricants (import)		0.0	0.0%	920.00
Bitumen		62.7	3.9%	488.00
Refinery own used Fuel		25.2	1.6%	
TOTAL Product value		1,600.4	100.0%	622.12
Murban		297.4	18.6%	611.44
Arab Light		766.7	47.9%	565.22
NGCondensate		136.1	8.5%	617.06
Forcados		400.2	25.0%	585.68
TOTAL Crude Oil costs		1,600.4	100.0%	583.33
Freight costs				15.38
Lightering				5.00
Refiners margin Gross				18.41
Refinery Operating expenses				10.50
Net refiners margin	**$/ton**			7.91
Net refiners margin	**$/bbl**			1.07
Total import cost crude	**mln USD**			**966.2**
Total profit/loss on refining	**mln USD**			**12.7**

With all the modifications in units, energy efficiencies gained, and better crude optimisation, the overall refiners margin is now positive at 1.07 USD/barrel or 12.7 million USD/ per year, compared to a negative in Scenario 1 of -0.65 USD/barrel loss with -6.1 million USD/per year .

This refinery operation can thus justify its existence and to survive in the longer term.

Note also that crude oil freight costs are higher than in the previous scenario due to the much more expensive Forcados crude voyage at approx 27 USD/ton. (Suezmax world scale rate 125% as observed and discussed in the assessment report)

Also the operating expense is higher due to the extra Platformer and Visbreaker associated costs.

The overall result is still a major financial margin improvement of 1.72 $/barrel or 18.8 million USD/per year compared to Scenario 1, which is significant on the still small scale of a 36.000 barrel day refining operation.

Trading Margin Calculation

The second part of the Scenario analysis is the Trading results of all product purchases, bought at AG refiners at Platts Fob AG, shipped to Bangladesh for average 22.50 USD/ton (25.000 ton vessels at WS 225) and sold domestically at the market import party price (Platts FOB Singapore).

TRADING RESULTS	Scenario 2			USD/ton Purchase Cost AG Platts	USD/ton Revenue import parity
		Imports (- export)		Platts AG Arab Gulf	Platts Sing basis
		Kton	%	2007-2010	2007-2010
LPG		32.7	0.7%	627.44	657.44
Naphtha		-81.6	-1.9%	654.65	652.06
Premium		72.9	1.7%	697.15	720.26
Regular		50.6	1.2%	691.05	713.92
Spirits		-9.0	-0.2%	669.65	667.06
Kero		145.9	3.3%	714.57	735.46
Jet Fuel		140.0	3.2%	714.57	735.46
Diesel		3005.7	68.3%	681.90	695.10
Jute/other oil		24.2	0.5%	671.90	685.10
Furnace oil		986.0	22.4%	422.48	438.00
Lubricants (import)		20.0	0.5%	920.00	920.00
Bitumen		37.3	0.8%	472.48	488.00
		-25.2	-0.6%		
TOTAL		4399.6	100.0%	629.53	644.51
Freight costs				22.50	
Lightering				0.00	
Trading margin Gross				-7.52	
Operating expenses	estimated			1.00	
Net trading margin			$/ton	**-8.52**	
Net trading margin			$/bbl	**-1.15**	
Total import cost products			mln USD		**2868.7**
Total profit/loss on trading			mln USD		**-37.5**

The trading part of this Scenario will still show a loss of 37.5 million USD as 4.4 million ton product is being imported, but it is less than in Scenario 1 because the refinery is producing more product so less needs to be purchased and the refinery makes a large part of the expensive HOBC high octane gasoline and Jet Fuel, which now do not need to be purchased.

Note:

- The refinery product output volume and the import volume add up to 6.0 million tons/year.
- The revenue side is Platts Fob Singapore; the market parity level for Bangladesh proposed domestic price.

Conclusion

Overall result for this Scenario 2	USD per Year
Profit on refining	12.7 million
Loss on importation	-37.5 million
Total loss for Scenario 2	-24.8 million

Still a loss, but an improvement of 21.2 million USD or almost half of the 46.0 million USD loss that was realised in scenario 1.

2.2.9 Required Investments for Scenario 2

Scenario 2 is the improved situation with regard to small modifications in the refinery process units. The volume of imported product is still high and in light of the port logistic limitations there will be the same minor investments required as in Scenario 1 to accommodate the increased flow of imported products.

All costs are estimates based on similar projects elsewhere:

Crude Unit Debottlenecking:	mln USD
Preflash unit Light ends rerouting, reflux and cooling system, stripper circulation pumps	1.7
Vacuum Unit ejector capacity	0.1
Hydrodesulphuriser reactivation	2.0
Platformer catalyst make up	0.2
Gas turbine CHP unit 2*4 MW/h and 350 ton/d steam.	9 0
Pump capacity to 3000 cbm/hr at Jetties RM 6 and 7	0.6
Extension to RM 6+7 loading arm+mooring if no 24 hour service	2.0
Total investment for Scenario 2	15.6

This investment and the crude oil choice optimisation caused an improvement of 21.2 mln USD (Scenario1 and 2 difference overall result) and payback is less than one year.

2.2.10 Scenario 2: financial result over a 10 year period.

Not surprisingly this Scenario 2 is financially still disappointing although much less dramatic than the on actual situation based Scenario 1.

It reflects the now sustainable refinery situation with a positive refiner's margin, but also the still necessary practice to meet demand with the expensive finished product imports.

Net present value/ IRR			Scenario 2								
interest rate	5.5%										
effective period	year	now	2	3	4	5	6	7	8	9	10
Investments	mln USD	-15.6									
refiners margin	mln USD	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
trading margin	mln USD	-37.5	-37.5	-38	-38	-38	-38	-38	-38	-38	-38
total margin	mln USD	-40.4	-24.8	-25	-25	-25	-25	-25	-25	-25	-25
NPV	mln USD	-$201.7									
IRR		NA									

The result is a 201.7 million USD loss over a 10 year period presented as a Net Present Value in today's money. With the overall product demand of 6 million ton per year this means on average a loss of 3.40 USD per ton domestically sold product (sold domestic at market parity price basis).

However it is much more interesting to look at the improvement in Scenario 2 compared with Scenario 1 with just a small (net difference 13 million USD) extra investment cost. This is a differential analysis that shows the net amounts as Scenario 2 minus 1.

Differential results Scenario1 and Scenario 2													
			DIFFERENTIAL RESULT										
Net present value/ IRR			scenario 2- scenario 1										
interest rate	5.5%												
effective period	year	now		1	2	3	4	5	6	7	8	9	10
Investments	mln USD	-13											
refiners margin	mln USD			18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
trading margin	mln USD			2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
total margin	mln USD	-13		21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
NPV	mln USD	**$139.1**											
IRR		**163%**											

The improvement of just a 13 mln USD investment, plus crude oil flexibility would add up to 139 million USD benefit over a 10 year period with just a 13 mln USD extra investment, and is equivalent to a Internal Rate of Return of 163%. It is evident that just very small adjustments can make a difference between a healthy operation and the now non sustainable ERL position.

Note: all revenue calculations were done on basis of Market Parity prices; Platts Singapore FOB. Any level of final consumer sales prices below the market parity will further deteriorate the bottom line results.

2.2.11 Pro/strengths and contra/weaknesses of Scenario 2

The only major difference between the current oil supply situation in Bangladesh and this Scenario 2 is the demanded volumes and the emphasis on increased product purchases and trading programs to meet that demand.

Pro and Strengths

- Minimal investment of 15.6 mln USD required
- Positive refiners margin of 1.07 USD/barrel
- Overall inland product quality improved due to reactivation of the Hydrodesulphuriser unit and the imports of good quality specification.
- No massive construction and other building activity.
- Existing storage facilities utilised at higher throughput.
- Scenario assumes implementation of international market price as basis for domestic prices.
- Introduction of CHP gas turbine new technology with major saving on utility bill.

Contra and Weakness

- Unrealistic to expect all oil product vessel movements to be feasible in Chittagong.
- Port is daytime service only and will give congestion and delays for all in/out movement.
- Product purchase activity loses another 37.5 mln $/year loss, total product supply result (for benchmark purpose) 24.8 mln $/loss per year.
- Port draft remains a major obstacle to an efficient crude oil direct discharge.
- Other ports are not capable to import even the smallest product vessels.
- Chartering costs are high and daily efforts require professional approach.
- No supply flexibility with the refinery only producing 27 % of the demanded products and demand yield remains distillate oriented.
- Dependency on foreign product import is high.
- Working capital requirements are high with most product purchases to be paid within 1 week of shipment.

2.3 Scenario 3: Modest Modernization and increase of production capacity at the current ERL refinery site

2.3.1 Brief Description

This scenario will describe improvements, modifications and adjustments to the ERL refinery configuration with a view to improve the volume throughput operation of the refinery and to a lesser extend the complexity of the units.

This scenario will, include the Balancing, Modernizing, Replacing and Expansion (BRME) of the facility. There will be no major conversion units and just an essential increase in Crude Oil processing capacity with vital support units such as a Platformer, Isomerisation unit, and Desulphurisation units. It is an addition to the current ERL refinery configuration without the modifications as described in Scenario 2.

Scenario 3 will concentrate on refined products production with basic units only.

The refinery economics will be depressed as crude distillation alone is in general not returning good margins. The volume of purchased products will decrease to minor balances while at the same time other products will have to be exported.

However investment is modest and the choice of crude oils will be contributing to better economics beside the volume yield for Kero, Jet Fuel and Diesel. This scenario will also look at a different crude oil base slate like in Scenario 2, aimed for direct contribution towards distillate production.

The refineries own Diesel output will be better in quality and will have a sulphur content of 350 ppm with also better driving properties due to the operation of sufficient Hydrodesulphurisation unit capacity. However the unit is small and can only handle a limited volume of feedstock. Overall sulphur in the distillate pool will approach 3000 ppm, depending also on the amount of low sulphur crudes in the slate.

The refinery Crude Unit operation is assumed to be capable to produce 4.5 million ton/year with the construction of a brand new 100.000 bbl/day Crude oil unit and 5.000 bbl/day Continuous Regenerating Reformer Unit (CCR) and 5000 barrel day Isomerisation unit besides the existing ERL units as described in the base case and scenario 2.

So here there are 2 refineries

- one the existing ERL as is today is and assumed here is that the old 33000 bbl/day CDU is to be on standby and in its place
- a second refinery, at the same place, which would be new, simplified, and much larger with a capacity of 100.000 barrel/day. It is supposed to be near or even integrated with the present site.

Natural Gas Condensates will all be blended into the crude oil feed and the new CDU design will allow condensate processing to 500.000 ton per year. (8 % on total crude oil)

Utility, power and steam requirements are higher in this 100.000 barrel/day scenario, and efficiency and reliability is increased by the necessary investment in Combined Heat and Power gas turbines.

This Scenario 3 will have to rely on the investment planned in a modern SPM crude oil supply system where crude oil supply vessels of 130.000-200.000 tons (Suezmax and Aframax) can discharge at sea anchoring points near Kutubdia and transfer the crude oil via pipelines to Chittagong. At the 100.000 barrel or even a 133.000 barrel/day (18.000 ton/day) refinery run rates there is no possibility to continue with cumbersome lightering operations as volumes are simply too large on a daily basis to be successfully handled at jetties 6 and 7 in this way. Even if larger and faster lightering vessels and jetty pumps and 24 hour port service are available in Chittagong then perhaps this will halve the current discharge time of 10-13 days to 5-6 days for a 130.000 ton mother vessel. In other words even if such speed can be achieved there is at maximum a 20.000 ton daily discharge in ideal circumstances (no waiting times, no storm delays etc)

In this Scenario there will be much less major product imports and all jetties can be used for product shipments going out from the MI out to depots and for export of to be balanced product.

The main purpose of this Scenario 3 is the attempt to meet the 6.0 mln ton/year product demand by a simple low budget refinery operation and to avoid the small product tanker delivered imports of expensive products and to avoid the congestion in Chittagong port.

There will be less emphasis on the refiners margin with the introduction of basic refinery units only to minimise the for this investment required capital.

A basic (simple configuration) refinery will put even more extra emphasis to optimise on the right crude oil choice as it is the first step to improve a refinery margin without the benefit of conversion units. Therefore widening the potential crude oil base slate, and operate the refinery units with daily attention to changing circumstances and to be flexible. These are the major tools to optimise on the refinery margin in this Scenario 3 and of course own refinery output prevent the avoidance of losses that are now made on the product importation as was demonstrated in Scenario’s 1 and 2.

This Scenario results are not or considerable less burdened by the negative results on trading of product purchases as seen in Scenarios 1 and 2 as the Scenario 3 refinery will be able to satisfy almost all demanded products .

2.3.2 Refinery Configuration and Operation

CDU

The entirely new Crude unit will be designed for 100.000 barrel per day and will include:

- Preflash tower heated by waste heat exchangers to relieve the lightest products from using main fractionator overhead capacity.
- A proper electrostatic Desalter capable to process 100.000 bbl/day matching the CDU capacity.
- A dual box furnace heater to use both gas and liquid fuels with proper convection reboiling coils for heat efficiency use elsewhere (Preflash Tower)
- Main fractionator with sufficient tray capacity in the distillates boiling range (175-350 C) to cope with 280 tons flow per hour. Bottom Steam injection to capture most of the 350+ Gasoil’s to cracking point 375 degr C.
- Good sized size side stripping vessels for Naphtha, Kero, Gasoil and bottom Heavy Gasoil/recycle.
- A Naphtha/LPG Stabiliser including a LPG and light Naphtha stripping unit equipped with a small amine absorber/regenerator for capture of all Hydrogen sulphide gasses.
- A Methane’s/Ethane capture section after the main stabiliser and its amine unit for use as furnace burner fuel and even for supply to utilities.
- A flare knock out drum capable to capture eventual excess gasses for re-use in an incinerator.
- New integrated larger Merox units for LPG (300 ton/day), and Kero, Jet Fuel. (2000 ton day)

The existing old 33000 barrel /day CDU will not be in operation in this scenario and be on standby or even mothballed for future use when actual demand is increasing over 4.7 mln ton/year.

Vacuum Distillation Unit (VDU)

The existing VDU from the old ERL complex will be redesigned to run on all produced Atmospheric residues from the CDU and allow maximum distillation of Vacuum Gasoil's.

Capacity based on a combination of crudes (lighter AG crudes, and low sulphur crude such as Forcados) will remain around 4.000 barrel day and will include:

- Main Vacuum fractionator with a minimum of 4 packed trays, allowing recovering Low sulphur type Light Vacuum Gasoil feedstock, beside a high sulphur heavier Vacuum Gasoil stream.
- Feedstock pipeline direct from Crude unit to Vacuum unit reboiler to minimise energy use. The direct fuel consumption of a modern high-vacuum unit is approximately 1% on intake

At the place where the heated feed is introduced in the vacuum column - called the flash zone - the temperature should be high and the pressure as low as possible.

This will obtain maximum distillate yield for blending into the Diesel fraction from the CDU and for Jute batch oil and Marine Diesel Gasoil. The flash temperature is restricted to about 420 ^{0}C, however, in view of the cracking tendency of high-molecular-weight hydrocarbons.

In this Scenario there will be no conversion units that will use the produced Vacuum Gasoil's. It is just the new Crude Unit using the existing Vacuum Unit for Bitumen manufacture and some extra processing of Low Sulphur Atmospheric residue from the low sulphur crudes like here Forcados.

New Continuous Regenerating catalytic Reformer

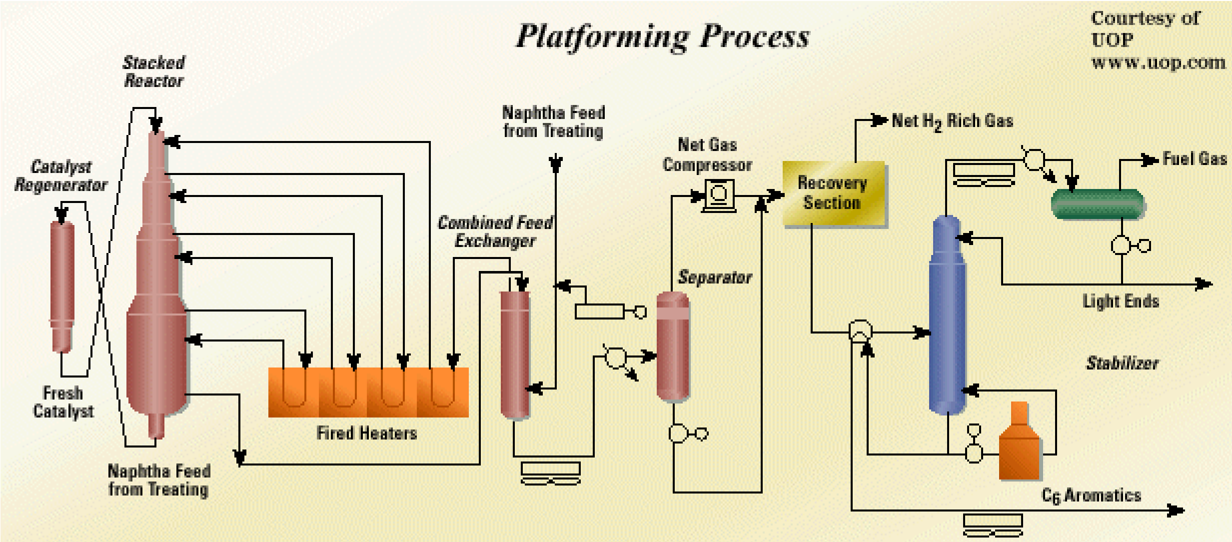
In this Scenario 3 the existing ERL Semi regenerative reformer will be shutdown and mothballed for possibly future use. This unit is less energy efficient and with the higher severity to produce HOBC type of octane's there is the disadvantage of regeneration cycles for reactivation of the catalyst.

Capacity of the Scenario 3 new Platformer unit is 5.000 barrel/day (600 ton/day) partly designed for the mode of operation of the available Heavy Straight Run Naphtha feedstock which is minimised in favour of Kero production. The design is based on a continuous regeneration of the catalyst which will prevent the necessity to shut the unit down for regeneration of the conventional build Platformer like the current ERL unit.

There will be a Naphtha Hydro treating unit which is integrated in the Continuous catalyst regeneration reformer (CCR) design.

Continuous catalyst regeneration reformers (CCR) units are characterized by continuous in-situ regeneration of part of the catalyst in a special regenerator, and by continuous addition of the regenerated catalyst to the operating reactors. As of recent developments, two CCR license versions available: UOP's CCR Platformer process and IPF/Axen's Octanizing process. The installation and use of CCR units is rapidly increasing due to the superior design over the old technologies of fixed bed reactor Platformers.

Schematic diagram of a typical continuous catalytic reformer unit in a petroleum refinery.



A CCR typically contains:

- A feed/effluent heat exchanger to minimize energy use,
- 4 furnaces, 4 reactors, and to be included
- A Naphtha hydrotreater for removal of all catalyst poisoning particles, sulphur, nitrogen, metals.
- A catalyst regenerator, continuous refreshing reactivating the catalyst.
- overhead recontacting section,
- net gas compressors, recycle gas compressor and
- A stabilizer column, including an Aromatics stripping section to remove Benzenes from the Platformate.

For economic reasons, the design capacities of CCR Platformer units vary from 500 - 4500 t/d. Operating pressures can vary over a wide range, units with from 3.5 bar (kg/cm2) up to 30 bar can be found, whereby the latest generation CCR's are typically at the lower pressure range.

This severity is much better than compared to Semi regenerative reformers that typically require 50 kg/cm2. A lower pressure enhances the endothermic reactions, which gives less cracking reactions and thereby a higher liquid yield.

The approximate investment in a CCR of 5000 barrel day is estimated at 35 million USD. (excluding he 10.000 barrel day CCR integrated Naphtha/Bensat Hydrotreater unit at estimated 20 million USD for CCR and Isomerate feed preparation and desulphurisation)

In such a continuous regeneration process, a constant catalyst activity can be maintained without unit shutdown for a typical run length of 5 - 6 years. The Platformer unit produces about 85-88% % liquid of 100-104 RON Platformate, 10% hydrogen and 2-5% LPG.

In addition to its role in gasoline production, the CCR Platforming process is a reliable, continuous source of high-purity hydrogen. This hydrogen is critical for the production of other fuel products such as high quality, low sulfur diesel from Hydrodesulphurization and Hydrocracking.

The CCR Platformer will allow all Premium and Regular grades gasoline's to be made locally and meeting the highest octane quality and sulphur requirements.

A new Isomerisation Unit

This unit is a new addition to the Gasoline manufacturing processes. Its purpose for this scenario is to convert the surplus light Naphtha which is produced from the CDU Naphtha stabilizer unit and convert this into a gasoline blending component. The design of the unit will be approx. 5000 barrels/day (560 ton/day).

Exports of Light Naphtha as under Scenarios 1 and 2 will not or hardly be required in this scenario. The economics are relative simple as the unit almost; for 98 % converts Light Naphtha into a high quality 80-85 RON gasoline blend component.

The value difference as Singapore Platts between Regular Gasoline and Naphtha is around 60 USD/ton.

The unit does not require high operating costs and therefore the upgrading value of an Isomerisation unit is very high. Operating cost is considered minimal with only 2 % losses but with adjustments likely recoverable as LPG.

Investment costs of the unit are relative low expressed as cost per barrel, at least much lower compared with Platformers and other conversion units.

The upgrading in this scenario is a 5 % crude yield as light Naphtha and conversion into gasoline blend component. At current naphtha-gasoline values of 50-60 USD/ton, Isomerisation contributes 0.50 USD/barrel crude.

A typical (once through) 5000 barrel day Isom unit would cost in the order of 9.3 million USD, compared to an equal sized CCR Platformer which costs 35 million USD.

What is Isomerisation:

Isomerisation processes rearrange straight chain or paraffinic hydrocarbons to branched isomers. The Isomerisation process utilizes the light Naphtha stream, Pentane and Hexanes; C5 and C6 as feedstock. In this case, the goal is to convert these paraffin's chains to Iso pentane and Iso hexanes. Light straight run naphtha is a typical feedstock for a common Isomerisation process. Variations of this Isomerisation process include benzene hydrogenation capability to meet low benzene content gasoline specifications. All Isomerisation feeds are desulphurized in the nearby CCR Naphtha Hydrotreater to prevent catalyst poisoning. Isomerisation of light straight run naphtha results in a valuable, high octane typically 80-88 RON, low sulfur, gasoline blend component.

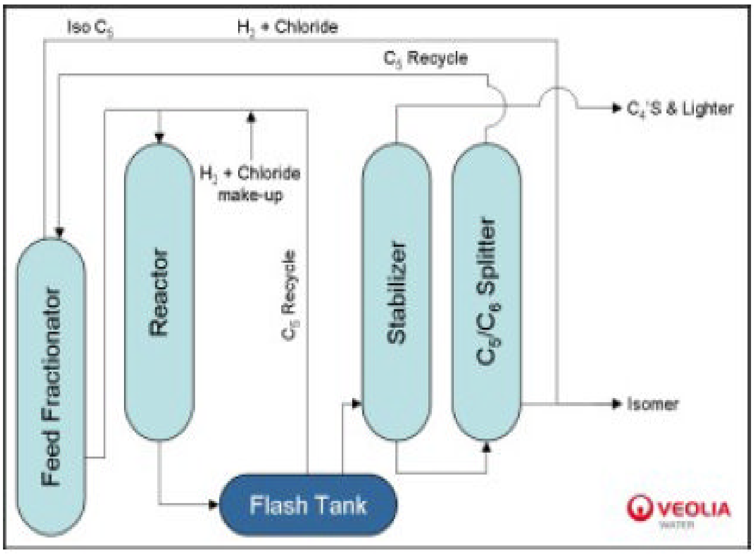
Since the introduction of the Penex process in 1958, UOP has been the leader in light naphtha isomerisation technology. In the years since, more than 220 UOP light naphtha isomerisation units have been commissioned. Today, UOP remains at the forefront of this technology, offering a broad range of processing options for light naphtha (C5/C6) including upgrading of low octane streams and elimination of benzene.

Most common design is the UOP Penex™ process and the UOP Par-Isom™ process; both are fixed-bed processes that improve the octane of C5/C6 streams by isomerising normal components to branched components using UOP's high-activity catalysts. The reaction conditions promote isomerisation and minimize hydrocracking.

There are two common options:

- Hydrocarbon Once-through – the light naphtha passes through the isomerisation reactor only once. Normal paraffin's are converted to iso paraffin's but the conversion is limited by equilibrium. Typical product octane's are in the 80-84 RON range.
- Isomerisation/DIH – A de-isohexanizer is used to recover and recycle unconverted normal hexane and low octane hexane isomers to the reactor system. RON values of 87-89 can be achieved.

Simple Isom unit schematic representation:



The Isomerisation unit can also be used successfully to meet low (less than 1% in US, Europe are common and even mandatory) Benzene Specifications.

This is done by saturating in the hydrotreater or even in a dedicated Isomerisation unit hydrotreater for all the benzenes from the Platformate splitter. Then these converted benzenes are isomerised into iso-hexanes. The process provides a cost effective means for removing unwanted benzene into high octane gasoline and can be applied in a variety of configurations ranging from light straight-run naphtha to reformate streams.

For this Scenario 3 we will use the simplest (UOP Penex design) Isomerisation Unit once through version with some recycling of the Platformate splitters benzenes.

The Hydrodesulphuriser Unit

This is the existing and reactivated small 1700 barrel/day ERL Mild Hydrocracker Unit to be converted back as Hydrodesulphuriser Unit as described in Scenario 2.

The unit's purpose and mode of operation is:

- To desulphurise and stabilise and hydrogenate the Visbreaker Distillates.
- To desulphurise and hydrogenate the light Vacuum Gasoil.
- To reduce the overall sulphur in the Diesel pool.
- To reduce and saturate the small stream of benzenes if there is no excess capacity in the CCR hydrotreater.

All costs to reactivate the unit will be the same as in Scenario 2. The new CCR unit will provide more than sufficient and much better quality Hydrogen for the Desulphurisation and Aromatics saturation. This allows using a more efficient catalyst; Nickel Molybdenum and likely the capacity of the small unit can be increased as a result by 10-20% without any further modification, although this estimate is not used in scenario 3.

The Visbreaker

This is the current existing Long Residue Visbreaker with a capacity of 10.000 barrel/day (520.000 ton year).

No major changes in the operation, except that part of the atmospheric residue feed will be a low sulphur long residue from Forcados crude which will reduce the overall sulphur content in the Furnace oil blend pool.

The estimated conversion for low sulphur long residue is estimated at 22 % residue into distillates while on high sulphur (Murban, Arab Light feed) this is 25 % as per actual performance.

Power Generation

Like in Scenario 2 there is the need for utility efficiency improvement and for an overall increase for electricity demand with a new much larger CDU and the CCR and Isom units.

It is proposed again to use a modern Combined Heat& Power Gas turbine with better reliability and efficiencies of 75% compared to conventional power and electricity steam turbine generation at only 32% efficiency. .

With the new 100.000 barrel day CDU, the new 5000 barrel/day CCR, 5000 barrel day Isom unit, the existing Vacuum plus Bitumen units, the reactivated 1700 barrel day Hydrodesulphurisation and the 10.000 barrel day Visbreaker the refinery power requirement will increase.

Introduced in this Scenario is a modern 12 (3 units of 4 MWh) MWh Combined Heat and Power technology Gas turbine unit, fired on natural and refinery gases.

Beside reliability there are the efficiency gains, which will be reflected in the lower refinery consumption and loss and thus lower operating costs as purchased gas is considerably less per barrel crude throughput. The CHP Gas turbine will also provide all medium pressure process steam requirements and if required additional high (over 20 kg/cm2) pressure steam required in the new crude units steam column bottom valves for partial pressure reduction and prevention of cracking at 375 degr C.

Other Utilities

Water supply

Process and utility water must be free of salt and other impurities. Although there is with the current ERL refinery a desalination Reverse Osmosis plant for 50 ton/hr, this is too small for a 100.000 barrel day operation. Recommended is to increase the capacity to 200 ton/hour. Although the utilities do not require steam for electricity generation with a CHP Gas turbine, there is still a requirement for process steam.

Oil/water separators

Improvement in environmental affairs is an obligation with a 100.000 barrel/day refinery.

Proper oil water separators are a requirement. Capacity should be at least 1000 barrel contaminated water (140 ton) per day. Proposed is to reactivate and improve the present location oil/water separator system.

Cooling capacity

No extra requirement is foreseen, but the existing cooling towers will be at maximum 300 cbm/hr capacity. However the new CDU and CCR plants will be very efficient in their energy use and the requirement for fin-fan and cooling of process water will be a fraction compared to the existing refinery requirement per processed barrel crude.

Summary of Scenario 3 Operating Units and Capacities:	
New Crude Distillation Unit	100.000 bbl/day
Vacuum Distillation Unit	4.000 bbl/day
New Cont Catalytic Reformer (CCR)	5.000 bbl/day
New in CCR integrated Naphtha/Kero hydrotreater	10.000 bbl/day
New Isomerisation Penex	5.000 bbl/day
Reactivated Hydrodesulphurisation Unit	1.700 bbl/day
Visbreaker	10.000 bbl/day
New Merox units (LPG, Kero, Jet Fuel)	800.000 ton/year
Bitumen Blowing Unit.	70.000 ton/year
New CHP unit	12 MW/h.
New RO water plant	200 ton/hr

2.3.3 Supply and Demand balance Scenario 3

In the two previous scenario's 1 and 2 only 20-26% of the total oil product demand was ERL refined product.

In scenario 3 with the construction of a much larger new 100.000 barrel day Crude Unit, a total of 4.5 million ton or nearly 75% is ERL refined product and just 25 % is then the net purchased product to satisfy the same assumed oil product demand of 6.0 million ton/year.

There is also the need to balance the other products as the produced refined product yield is not equal to the demand yield.

This balancing activity is becoming an interesting and very active role for the Supply and Planning department.

Demand remains driven by Distillates, Kero and Diesel, but now the major portion of Kero, Jet and Diesel distillates is refined and there is no or hardly import of Furnace fuel oil as a result of the 53 times increased refining capacity compared to the scenario 1 and 2. Jet fuel is all produced now by ERL so (expensive) imports are not necessary, and the same applies to ERL now producing all the MS Regular and HOBC Premium gasoline, and even surplus of gasoline to be exported into the region basis Platts FOB Singapore less the Chittagong-Singapore freight costs.

Sine Jet Fuel and 95 Unleaded Gasoline's are among the most expensive products the trading results will improve.

There is however still demand imbalance in particular for Diesel and there is an overall 1.5 million ton/year outright product deficit.

On a daily average basis there is an export of 1.600 ton Gasoline's and some Jet Fuel, and an import of 5800 ton per day of Diesel, resulting in a net import of 4200 ton/day.

In the previous scenario's total import was around 13000 ton/day and questionable if such daily average volume could indeed be handled. This scenario requires only a movement of 5800 ton day import and 1600 ton/day export and thus a total activity of 7400 ton/day through Chittagong port, almost halving the movements from Scenario 2.

Bangladesh supply and demand					Scenario 3		
In Kton	Petroleum product Demand		Refinery output		Product Import (neg =export)		Import per day
LPG	50,0	0,8%	49,6	1,1%	0,4	0,0%	0,0
Naphtha			81,5	1,8%	-81,5	-5,3%	-0,2
Premium	125,0	2,1%	199,4	4,5%	-74,4	-4,8%	-0,2
Regular	125,0	2,1%	250,7	5,6%	-125,7	-8,2%	-0,3
Spirits	10,0	0,2%	66,0	1,5%	-56,0	-3,6%	-0,2
Kero	300,0	5,0%	289,0	6,5%	11,0	0,7%	0,0
Jet Fuel	350,0	5,8%	600,6	13,4%	-250,6	-16,3%	-0,7
Diesel	3 500,0	58,3%	1375,6	30,8%	2124,4	138,5%	5,8
Jute/other oil	50,0	0,8%	66,1	1,5%	-16,1	-1,0%	0,0
Furnace oil	1 370,0	22,8%	1355,4	30,3%	14,6	1,0%	0,0
Lubricants (import)	20,0	0,3%	0,0	0,0%	20,0	1,3%	0,1
Bitumen	100,0	1,7%	66,2	1,5%	33,8	2,2%	0,1
Refinery own used Fuel			66,0	1,5%	-66,0	-4,3%	
TOTAL	**6 000,0**	**100%**	**4 465,9**	**100,0%**	**1 534,1**	**100,0%**	**4,2**
Murban			1161,4	26,0%			
Arab Light			1340,1	30,0%			
NGCondensate			178,7	4,0%			
Forcados			1786,8	40,0%			
Crude Oil			4 467,0	100,0%	4 467,0		12,2
Crude+Products					6 001,2		16,4

Important is the crude oil supply which takes the place now of the refined product import volumes. Assumes is that crude oil supply is pumped to the refinery via the new SPM system build near the Kutubdia island anchoring point and pumped from there to Chittagong.

This is a realistic scenario if there is only interest for capacity increase with fairly minor but key investments. If these are made and the already discussed different operating attitude is implemented then this refinery operation will be very close to break even and more important even the dependency on importation of all sorts of refined product is reduced by 300%. This Scenario 3 will also reduce the previous reported losses on product importation.

2.3.4 Limitations to Scenario 3

The increased crude oil requirement and the addition of new crude oil types will require appropriate storage and handling.

As discussed earlier this Scenario 3 assumes that a sophisticated SPM in at least 17 m draft water is in place and is able to accommodate at high seas Suezmax vessels of 130-175.000 ton size with a minimum pumping capacity of 3000 CBM per hour.

Crude oil runs with the new 100.000 barrel/day CDU are now approx 13.500 ton per day, and therefore will require a constant feed from the SPM into the refinery storage tanks at Chittagong to maintain uninterrupted runs.

At a SPM Capacity of 3000 cbm/hour minimum there will then on average 5 hours per day of continuous pumping from vessels to shore, whether directly to Chittagong or via intermediary buffer tanks somewhere near the SPM anchoring point.

The alternative is a system where large and fast pumping capability lightering vessels (50.000 tons) transport the crude oil from deep draft Kutubdia to Chittagong's 11-12 meter draft Sandwip Channel and discharge into a SPM or directly to an into the sea stretched Jetty connected to the 3 km distant refinery tanks.

Crude oil Supply Planning and Scheduling

The crude oils supplied will come from at least 4 different qualities (Arab light type for bitumen, other indigenous high sulphur, the local Nat Gas condensates and the low sulphur/high distillate content type crudes).

This will require good forward planning of loadings and arrivals to prevent congestion at the SPM. Also commercial terms need to be negotiated with at least 4 different suppliers and in line with international market levels.

Much more than in Scenario's 1 and 2 there will be efforts and the need to charter Crude oil vessels in the right lifting windows and for the right loading terminals. Demurrages are expensive and need to be avoided in particular with the shallow refiner's margin in this Scenario.

Crude Oil Storage

Although ERL has sufficient capacity to maintain a run rate of 13500 ton/day with its 300.000 ton storage capacity, there is the aspect of optimising on vessel size; Suezmax which are between 130.000 and 175.000 ton DWT. Using these vessels will take half of the available storage tanks, while the other half is being used for the daily refinery runs.

This can be done, but with the introduction of low sulphur crudes there will be the requirement to keep crude oils segregated in order to keep the advantages of low sulphur (fuel and distillates) blending. This segregation would absorb in itself half the available storage while other specific high sulphur crudes also need to be segregated for preserving the right qualities to make Bitumen.

ERL's current storage of just over 300.000 cbm is therefore now a limitation and one new tank, or two smaller 50.000 cbm tanks capable to hold 100.000 tons will need to be added and such expansion will give that flexibility to run a variety of crude oils supplied by the optimum choice of vessel size.

Product Storage

In the assessment report and in Scenario's 1 and 2 there was no necessity to increase the finished product storage capacity. This is both ERL and the MI storage tanks together. Where in Scenario 1 and 2 storage for import of products was sufficient so will also increased production and less importation make no extra requirement.

Possibly the refinery will have to change the tankage and dedicated product service, with pipeline bridges and corridors redesigned.

But the overall (ERL and MI) product storage of 573.000 cbm should be acceptable for a 100.000 barrel day crude run and the resulting light end products output.

One exception is the quantity of LPG gas.

LPG output is more than doubling and the 2 current spheres available; 2000 cbm total capacity are not sufficient to hold the LPG for longer periods or when emergencies arise if LPG offtake is interrupted. Although with good planning on daily offtake the current capacity will be sufficient.

It is however suggested and recommended to build one other sphere of 2000 cbm capacity

The other area is the heavy Furnace oil storage facilities.

With much more Furnace oil produced and transported via very small 300-1000 ton river boats to Power Station facilities in Bangladesh there will be congestion as Fuel oil loading is slower, but also Fuel Oils need to be kept segregated from the clean line system.

Monthly Fuel oil production is 115000 tons and ERL will also require intermediate (atmospheric and vacuum residue) storage for the Visbreaker and for blending.

To safeguard uninterrupted operations both the refinery as well as loading to barges, a total of 75000 ton extra storage (3 tanks of 25.000 ton) is required. There is a dedicated Fuel Oil line to the Crude Oil Jetty 7 (and possibly also to jetty 6), which is now almost obsolete with all crude oil being discharged at the Kutubdia Anchoring SPM.

This jetty can now serve the Fuel oil shipments to the power station customers.

The available land for building new units

The current ERL refinery plus storage tanks and other logistics occupies approx. 195 acres of land. It is widespread build, and there is sufficient room to accommodate a new CDU, CCR, CHP Gas turbine and Isomerisation Units.

The largest unit is the 100.000 barrel/day CDU with integrated Merox section which would in today's compact building design occupy less than 40.000 square meter or approx 10 Acres. The other units likely require a similar space. All units should be built very close together to minimise efficiency losses and residence time in pipelines and between intermediate storage tanks.

Some of the warehouse/ office buildings may have to be (partially) removed, although the empty spaces around the current CDU and VDU are sufficient for alt least the CCR and Isomerisation units while the CHP Gas turbines and ARO unit do not require much space and should be build close to the existing power and water facilities to benefit from the already present electricity, water and steam infrastructures.

2.3.5 Crude Oil Choice for this Scenario 3

The same crude oil types, Arab Light type for Bitumen quality manufacture, Murban type for general high sulphur 'easy to run' crude and low sulphur high distillate type such as Forcados (or similar) and of course the local produced Nat Gas condensate will be the basic feedstock slate in this Scenario.

Crude oil choice, as explained in the introduction, will make a real difference in the quality and the quantity of the production yield in particular in this Scenario where just a large Crude unit without hydrodesulphurisation must be fed with Low Sulphur Crude oil to limit the Diesel and Kero and Furnace Oil sulphur.

The crude choice will also change as there are higher freight costs for the Nigerian crude (Nigeria- Chittagong at WS 125% is approx 27 USD/ton, compared to AG- Chittagong at approx. 13 USD/ton.

Freight rates change and all freight numbers are indication only.

In this Scenario 3, the amount of low sulphur crude is increased to 40 % of the base slate as imports of good quality products are now considerably less and the sulphur balance can (without large Hydrodesulphurisation) only be controlled by low sulphur feedstock. However the main reason for Forcados type crude remains the relative wide distillate yield and of course the basic margin economics of the crude itself as explained in Scenario 2.

In this Scenario 3, crude choice optimisation is very important as there are no residue upgrading units and the majority of margin contribution has to come from the basic CDU distillation economics and for 10-15% from the gasoline conversion processes like the Isom and CCR units.

Linear models such as from Bonner &Moore RPMS – Refinery & Petrochemical Modelling System and the Aspentech. PIMS – Process Industry Modelling System and recent developed Dynamic Programming simulation of refinery runs include this crude oil optimisation facility, which is a must have in any professional oil company as there are too many variables and too high monetary impact from day to day operational and commercial decisions.

2.3.6 Product Qualities Scenario 3

With the much larger crude runs and resulting volumes in Diesel and Fuel Oil there is, as explained above, only the quantity of Low Sulphur Crudes in the base feedstock to control sulphur in the products.

There is no major desulphurisation of Kero and Diesel (except the small 1700 barrel/day reactivated Hydrodesulphuriser for processing of some Light Vac Gasoil and the Visbreaker Distillate) and the natural sulphur in the crude oil choice is the only variable to set the overall sulphur.

The refinery produces 75 % of the products and import of mainly the remaining Diesel is 25%.

With a 75% base crude oil feedstock slate (of 44% Low Sulphur (Forcados and Nat gas Condensate and 56% medium to high sulphur), and imports of 25% of 350 ppm Diesel the expected overall quality is 0.3 % sulphur or 3000 ppm in the Diesel (and 0.13% in the Kero pool).

The Gasoline production from the CCR and Isom units have all been pre-treated in the new build integrated Naphtha Hydrotreater unit and sulphur will be below 100 ppm, as per most accepted standards in the region.

Also benzene content in Gasoline will now be below 1% after the new CCR Platformer splitter and recycle of benzene rich light Platformate in the Isom Unit.

Heavy Fuel Oil sulphur will be at or just below 1.3 % with most of the Arab Light residue, which has the highest sulphur content, being converted to Bitumen.

The majority of the Fuel Oil will be a blend of Forcados and Murban residue with the remaining Arab Light fuel oil.

Key product test specifications

		ERL actual situation	Scenario 3	Target
Light Naphtha				
Paraffins	%vol	85		
Doctor test		Positive	Negative	
Lead	ppb	8	<1	
Vapour Pressure	KPa	84		
Gasolines unleaded				
Octane Research		95	95, 92, 88	
Benzene	% wt	5	1%	1
Sulphur	ppm	250	<100	100
Oxygenates	%wt	NA		
Aromatics	%wt	NA		
FBP	C	210		
Vapour Pressure	KPa	85	<85	
Jet Fuel A1				
Defstan 91-91**		no production	production	production
Kerosine household				
Distillation IBP	C	160	unchanged	
Smoke point	mm	20		
Flash point	C	40		
Sulphur	ppm	2850	1300	350
Diesel				
Cetane Index		50	unchanged	
Sulphur	ppm	2800	3000	350
Cloudpoint	C	NA		
Flashpoint	C	39	55	55
Furnace Oil				
Sulphur	%wt	3.5	1.3	2.0

In Scenario 3 the Fuel oil sulphur spec is well below the set target, as a result of the large quantity of low sulphur crude oil in the CDU feedstock. This is as such a positive development because inland PowerStation generation will burn this furnace oil and cause a much lower environmental burden with a 1.3% s Fuel oil compared to a 3- 3.5% Fuel Oil that would be there with a full high sulphur Arab light+ Murban crude oil slate.

However Low sulphur crude is more expensive.

2.3.7 Efficiencies in Scenario 3

In Scenario 3 there are major efficiency improvements both in the refinery processing and the utilities compared with the previous scenarios.

- Process units. The new CDU will have the latest design and thus also produce the best efficiency gains every where in the process, from preflash unit to reflux, cooling, heat exchangers and capture of refinery gasses for re-use in the furnace/heaters.
- 2. The CCR 3 main furnaces are much more efficient compared to the current old Semi regenerative Platformer and also the Isomerisation unit which only requires process heat to 200-230 deg C.
- 3. The 12 MW/h (installed as 3 units *4 MW/h) CHP gas turbines will provide around 70-75% overall efficiency as they are also used to provide the whole refinery of medium and high pressure steam or even use any excess steam for steam turbine and further electricity generation use after reheating in the CHP afterburner using refinery gases or even Flare gas. Current old technology conventional steam generators are just over 30 % efficient.

The refineries own use, consumption and loss of this refinery is just over 1.6% which is a reflection of its efficiency gains compared to the current use of 2.8%.

2.3.8 Economics of Scenario 3

As was done in scenario 1 and 2, this scenario 3 setup will have its own profit and loss estimate for the refinery and the products purchase /trading part, and is based on calculated yields and Platts prices (see assumptions).

Operating Expenses

Due to the improvements in Combined Heat & Power (CHP) and process unit energy efficiencies the overall operating expenses drop from the 10.50 USD/ton in the previous scenario to 8.50 USD/ton in Scenario 3. Of course the total expenditure amount rises with the increase in process capacities, but the main items causing this rise is the depreciation (4% per year) of the 2 main investments in the Single Point Mooring at Kutubdia Anchoring and the investment in the CDU, CCR, Isom, CHP and other units described.

Opex

scenario 3

		ERL		
throughput	crude tons	4,467,000		
	feedstock	0		
number of staff scen 3		450		
location type		sea/coastal		
supply/offtake		vessel/ SPM		
configuration		simple		
depreciation period major inv.	years	25		
	usd/mln	usd/bbl	%	
salaries/wages	4.5	0.14	13.6%	
other employee cost	2.3	0.07	6.8%	
chemicals	0.9	0.03	2.7%	
repair/maintenance	2.7	0.08	8.2%	
spare parts	1.0	0.03	3.2%	
fuel,power/water	0.5	0.01	1.5%	
gas purchase	4.2	0.13	12.7%	
insurance	0.8	0.02	2.3%	
crude oil handling*	7.0	0.21	21.2%	
shutdown	0.1	0.00	0.2%	
transport	0.1	0.00	0.2%	
depreciation**	9.0	0.27	27.2%	
other cost (catalyst)	0.1	0.00	0.3%	
Opex all	33.1	1.00	100.0%	
Opex excl deprec	$/bbl	0.73		
Opex incl deprec	$/ton			7.45
Visbreaker	1.5			1.05
new opex scen 2				**8.50**
*SPM, pipeline 25 y depr	175.0			
**CDU, CCR,ISOM 25 y depr	225.0			

There is no cost for regeneration of the Platformer catalyst, as the CCR unit will only be shut down after 4-5 years and will need general overhaul, and the same applies the Crude Oil Unit, which only will require a planned turnaround every 5 years.

Benefits are a much better efficiency for the CHP Gas turbine compared with the conventional fired steam generators costing less and a 4.2 mln USD gas purchase at world market parity price of 4.35 USD/mmBTU and equivalent to approx 11 Taka/Cbm.

Refinery Margin Calculation

The refinery margin is the difference between the revenue of all refined products, valued at the market parity price for Bangladesh Platts FOB Singapore, less the crude oil FOB load port purchase costs, less the freight on Suexmax class vessels and less the operating costs, with depreciation on all new major investment now included.

The result is negative, because this Scenario has just a Crude Unit with a Platformer and Isomerisation, and there is no residue upgrading. On the other hand there is a relative low investment amount required and what is very important a by far majority of all products is produced now in Bangladesh and just 25 % is imported. Important products as Jet Fuel and a large portion of the Diesel are now under own control.

REFINERY RESULTS	Scenario 3			USD/ton
		Refinery output		Platts Sing basis
		Kton	%	2007-2010
LPG		49.6	1.1%	657.44
Naphtha		81.5	1.8%	652.06
Premium		199.4	4.5%	720.26
Regular		250.7	5.6%	713.92
Spirits		66.0	1.5%	667.06
Kero		289.0	6.5%	735.46
Jet Fuel		600.6	13.4%	735.46
Diesel		1,375.6	30.8%	695.10
Jute/other oil		66.1	1.5%	685.10
Furnace oil		1,355.4	30.3%	438.00
Lubricants (import)		0.0	0.0%	920.00
Bitumen		66.2	1.5%	488.00
Refinery own used Fuel		66.0	1.5%	
TOTAL Product value		4,465.9	100.0%	612.18
Murban		1161.4	26.0%	611.44
Arab Light		1340.1	30.0%	565.22
NGCondensate		178.7	4.0%	617.06
Forcados		1786.8	40.0%	585.68
TOTAL Crude Oil costs		4,467.0	100.0%	587.49
Freight costs				18.56
Lightering				0.00
Refiners margin Gross				6.12
Refinery Operating expenses				8.50
Net refiners margin	**$/ton**			-2.38
Net refiners margin	**$/bbl**			-0.32
Total import cost crude	**mln USD**			**2707.3**
Total profit/loss on refining	**mln USD**			**-10.6**

Operating expenses are considerably lower and are for a large part the depreciation of SPM and Refinery CDU units.

With all the investment in units, energy efficiencies gained , and better crude optimisation the overall refiners margin is just negative at 0.32 USD/barrel or 10.6 million USD/ per year, compared to a negative in Scenario 1 of -0.65 USD/barrel loss with -6.1 million USD/per year .

This refinery operation can almost justify its existence and with extra cost reduction efforts including a longer depreciation period than the 25 years here used, it should survive in the longer term.

Note:

The average crude oil freight costs are higher than in the previous scenario due to the much more expensive Forcados crude voyage at approx 27 USD/ton. Compared with 13 USD/ton for the AG- Chittagong voyage of Murban and Arab light freight. (all freight at Suezmax world scale rate is set at 125% as observed and discussed in the assessment report). The Freight for Nat Gas Condensate is also 13 USD/ton and reflects the inland waterway, rail and other costs associated with transport from the Gas fields to Chittagong.

Trading Margin Calculation

The second part of the Scenario analysis is the Trading results of all product purchases and sales as a result of the Balancing of the refinery output with the demand,

Diesel is the only major net purchase now bought at AG refiners at Platts Fob AG, shipped to Bangladesh for average 22.50 USD/ton (25.000 ton vessels at WS 225) All products are sold domestically at the market import party price (Platts FOB Singapore) and all exports (negatives in below table) are assumed to be sold at Platts Fob Singapore less the 16.50 USD/ton (2.3 USD/barrel) freight Chittagong-Singapore for 25.000 ton vessels.

Singapore market is one of the three major international oil trading centres, with Houston for the US Gulf region and Rotterdam for the European and Mediterranean Region. Singapore markets are for most products in deficit due to the increased demand from major consumer countries like China, India, S Korea and successful Asian development countries such as Vietnam, Philippines and others.

The oil product surpluses from this Scenario will have no major problem to find buyers.

TRADING RESULTS	Scenario 3			USD/ton Purchase Cost AG Platts	USD/ton Revenue import parity
		Imports (- export) Kton	%	Platts AG Arab Gulf 2007-2010	Platts Sing basis 2007-2010
LPG		0.4	0.0%	627.44	657.44
Naphtha		-81.5	-5.3%	654.65	652.06
Premium		-74.4	-4.8%	697.15	720.26
Regular		-125.7	-8.2%	691.05	713.92
Spirits		-56.0	-3.6%	669.65	667.06
Kero		11.0	0.7%	714.57	735.46
Jet Fuel		-250.6	-16.3%	714.57	735.46
Diesel		2124.4	138.5%	681.90	695.10
Jute/other oil		-16.1	-1.0%	671.90	685.10
Furnace oil		14.6	1.0%	422.48	438.00
Lubricants (import)		20.0	1.3%	920.00	920.00
Bitumen		33.8	2.2%	472.48	488.00
		-66.0	-4.3%		
TOTAL		1534.1	100.0%	702.66	715.27
Freight costs	**20-25000 ton**			22.50	16.40
Lightering				0.00	0.00
Trading margin Gross				-6.83	
Operating expenses	estimated			1.00	
Net trading margin			$/ton	**-7.83**	
Net trading margin			$/bbl	**-1.06**	
Total import cost products			mln USD		**1112.5**
Total profit/loss on trading			mln USD		**-12.0**

The trading part of this Scenario 3 show a loss of just 12 million USD, but it is far less than the 37.5 million USD in Scenario 2 because the refinery is producing more product so less needs to be purchased and the refinery makes all of the expensive HBOC gasoline and Jet Fuel, which now do not need to be purchased and a major portion of the Diesel.

Conclusion

Overall result for this Scenario 3	mln USD per Year
loss on refining	-10.6
A loss on importation and output balancing	-12.0
Total loss for Scenario 3	-22.6

Compared to Scenario 2 which had an overall loss of 24.8 mln USD, this Scenario 3 is financially marginally by 2.2 million USD/year better.

However there is a major advantage as there is a large reduction in purchase and trading losses and the full potential to reduce the refinery losses further. The far greater independency from imports is also evident and of strategic value.

Scenario 3 is therefore much better than the previous ones as control over Bangladesh oil product supply is now under own management and responsibility.

Also aspects like trading, refining and managing complex organisations is an intangible asset that as such has no price, but is nevertheless a major asset for the country.

2.3.9 Required Investments for Scenario 3

Scenario 3 is the improved situation with regard to a major capacity enlargement in the refinery process units. The volume of imported product is considerably less and in light of the port logistic limitations there is now the investment in a SPM /pipeline system which we understand is approx 175 million USD. This project is already being studied and even implemented. The cost of this investment is not included as we assume the commitment is already made and also the comparability with other scenarios would be distorted. (However SPM depreciation costs is taken into account).

In case of delays of the SPM project, there is the alternative to use large lightering vessels for loading from the mothervessel at Kutubdia and discharge at the Sandwip Channel to be build SPM or Jetty connected to the ERL site in Chittagong. (see also Scenario 4).

In the Scenario 3 investment is therefore the refinery, storage facilities and immediate port logistics.

All costs are estimates based on similar projects elsewhere and on the valuation methods described by the Petroleum Refining Handbook 2004 (fourth edition 2001: James Gary and Glenn Handwerk), revision/update in O&G journal 2007.

All estimates are indicative only and subject to change.

	mln USD
New 100.000 bbl/day CDU (plus LPG, distillate Merox	103.0
New 5000 bbl/day Cont Regenerative reformer (CCR)	35.3
New 5000 bbl/day Isomerisation Unit	9.3
New 10.000 bbl/day Naphtha Hydrotreater	19.9
Vacuum Unit ejector capacity	0.1
Hydrodesulphuriser reactivation	2.0
Gas turbine CHP unit 3*4 MW/h and 450 ton/d steam.	15.0
Crude oil storage 100.000 cbm	11.5
Fuel Oil storage 75.000 cbm	8.6
LPG sphere plus pressure control valve/unloading rack	3.2
Water plant expansion 200 t/d	1.0
API oil/water separation	0.5
Investment for Scenario 3	209.4
Contingency 10%	20.9
Total estimated investment Scenario 3	230.3

2.3.10 Scenario 3: Financial Result over a 10 year period

This Scenario 3 has so far been the highest financial impact among the previous ones.

It reflects the now almost sustainable refinery situation with still a marginally negative refiner's margin, but also a much reduced importation program and less expensive finished product imports.

Net present value/ IRR	**Scenario 3**										
interest rate	5.5%										
effective period	year	now	2	3	4	5	6	7	8	9	10
Investments	mln USD	-230.3									
refiners margin	mln USD	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
trading margin	mln USD	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12
depreciation cash return	mln USD	16	16	16	16	16	16	16	16	16	16
total margin	mln USD	-236.9	-6.6	-6.6	-6.6	-6.6	-6.6	-6.6	-6.6	-6.6	-6.6
NPV	mln USD	-$268.0									
IRR		NA									

The Net Present Value is a negative 268 mln USD, and well above the NPV in Scenario 2 of negative 201.7 mln USD, but well below Scenario I of negative 349 mln USD.

The difference with Scenario 2 could be seen as a price paid for:

- Security of supply
- Building up of a sustainable oil infrastructure.
- A better quality product quality (sulphur and aromats) supply
- Better supply reliability.
- Potential for further improvement in performance
- Capacity building in human resources meeting international standards.

2.3.11 Pro/strengths and contra/weaknesses of Scenario 3

The major difference between the current oil supply situation in Bangladesh and this Scenario3 is the refined product portion of total demand now at 75% volumes and the reliability and quality of product supply

Pro and strengths

- Modest investment of 230 mln USD required
- Sharp reduction of loss making purchase/trading importation program.
- Overall inland product quality improved due to reactivation of the Hydrodesulphuriser unit and the introduction of low sulphur crudes.
- Almost Break even refinery operation due to efficiencies of new technology.
- Existing storage facilities better utilised at higher throughput.
- Scenario assumes implementation of international market price as basis for domestic prices.
- Introduction of CHP gas turbine new technology with major saving on utility bill.
- Product sulphur and aromatics qualities improved with new CCR/Isom units.
- Better long term reliability of country oil product supplies.
- Reduction of congestion in Chittagong port with introduction of SPM/pipeline crude supply.

Contra and weakness

- Still overall loss of refining and trading activities to 22 mln USD/year.
- Balancing product yield with demand yield leads to physical movement and product export.
- Other ports are not capable to import even the smallest product vessels.
- Daily supply efforts require professional approach.
- Dependency on foreign product import is less but still 25 %.
- Working capital requirements are high with crude oil payments to be paid within 30 days after Bill of Lading. Non payment is penalised with loss of credibility.
- Investment requirements need 230 mln USD to be funded (at international cost of capital).

2.4 Scenario 4: Full Modernization of ERL Refinery with addition of new units to be built in Chittagong

2.4.1 Brief Description

This Scenario will take both capacity expansion and yield improvement at the existing ERL location into account.

The objectives and goals for Scenario 4 are:

- Increase in refining capacity to satisfy a 6.0 million ton/year oil product demand.
- Maximise the production yield towards distillates, in particular Diesel and Kero.
- Meet product quality specification standard for the region.
- A sufficient profitability to sustain long term survival.
- Optimisation of a variety of crude oil supplies, including the entire local produced Nat Gas Condensates.
- Maximum use of all existing facilities (storage and other logistics) to minimise additional investments.
- Maximum process efficiency in both process units and utilities.

Investment will be substantial and requires major financing, but also the refiner's margin and product volume output will improve which will provide the financial backbone for the project justification and repayment.

- Add to the existing 33000 bpd ERL configuration at Chittagong a second new Crude Distillation Unit (CDU) of 100.000 bpd capable to produce 6 million tons oil products per year, as described in Scen 3.
- Add a new 45.000 bpd Vacuum Distillation Unit (VDU) capacity,
- A new 5000 bpd CCR Platformer, and for the Light Naphtha an 5000 bpd Isomerisation Unit also capable to take the stripped gas condensates from the Gas fields besides the CDU light naphtha. (as was proposed in Scenario 3)
- A new 50.000 bpd Hydrodesulphuriser, to desulphurise all CDU and Visbreaker/ Thermal Cracked produced distillates (Kero+ Diesel) to at least 350 ppm sulphur but capable to meet 50 ppm.
- Single Stage or 2 Stage 20.000 bpd Recycle Mild Hydrocracker capable to process an extra Diesel cut from the Vacuum Gasoil fraction 375-to 430 deg C.
- A new 60 ton/day Hydrogen production unit.
- A new 15.000 bpd Thermal Cracker to be fed with Vacuum Residue.
- Amine Absorber/regenerator units and Sulphur recovery units for adequate Hydrogensulphide, mercaptans and sulphur removal.
- New and reliable 37 MW power generation system based on a Cogen efficient Combined Heat Power Gas turbine.

For other services in oil storage and logistics there will be a review of all current ERL and MI facilities, pipelines, jetties, flare, oil catchers, water, and smokestacks to be used in this enlarged and sophisticated processing capacity scenario where possible.

The existing 33000 barrel/day ERL refinery (CDU and 4000 bpd Vacuum/Bitumen Unit and 10.000 bpd Visbreaker) are in operation and is to become a part of the total setup.

These units where possible are modernised and made ready for a more efficient operation. It is not correct to shut all current ERL units as in particular CDU and Visbreaker are relative modern and still well performing units. The very small and less efficient Platformer and MHC unit will be shutdown and mothballed since their function is taken over by modern new and much larger units.

Also there will be further expansion in the use of distillate rich crude oils in the crude oil feedstock slate, like Forcados, Nat Gas condensate, but also very heavy and cheap crudes that can now be introduced with the sophistication of the new facilities and further enhance the profitability and refiners margin.

The refinery can only properly operate with the SPM system as planned and described in Scenario 3. Crude oil supply is organised without lightering vessels and pumped directly or via buffer storage from the deep draft SPM to Chittagong. The alternative is a system of large fast moving lightering vessels serving between Kutubdia and the to be build Sandwip Channel discharge point.

Scenario 4 is focussed on maximisation of sustainability, profit margin, avoidance of major import of Diesel and other light products and thus in dependent of finished product supplies from other countries. There is a substantial investment in modern latest generation processing technology, with the new Vacuum Distillation Unit and the Hydrocracker and Thermal Cracker at the centre of this scenario 4.

At the centre of this setup is the new 100.000 barrel day Crude Unit, a modern 45.000 barrel day Vacuum Unit which will produce a Vacuum Gasoil fraction that is feedstock for the Hydrocracker and the Vacuum Resid fraction that will be further cracked in a Thermal Cracker for extra distillate production.

This refinery will need sufficient hydrogen, not only to remove all sulphur from the oil products, but also as additional hydrogen supply to the Hydrocracker and to reduce the instability and aromaticity of the thermal cracked products.

Hydrogen is produced by the 5000 barrel/day CCR Platformer, but this hydrogen will be entirely used in the new 50.000 barrel day Hydrodesulphuriser.

The 20.000 barrel day (2850 ton day) Hydrocracker will use between 1.5 and 2.3 % wt Hydrogen for the Hydrocracker process that will have to be produced in a new (60 ton/day) steam reformer Hydrogen Unit.

The refinery economics in this Scenario have to be positive to repay for the substantial investments. In general crude distillation with major conversion units such as Hydrocracking and Thermal cracking alone will be returning in the long run good refiner's margins. The volume of expensive purchased products will also decrease to relative to the overall output minor imbalances which will involve both imports as well as exports but essentially total oil product made available is equal to the total demand.

Investment is substantial with the introduction of a modern Vacuum Unit, Hydrocracker, Hydrodesulphuriser and Hydrogen units. Again as in previous scenario's the choice of crude oils will be further contributing to better economics beside the volume yield for Kero, Jet Fuel and Diesel.

This scenario will use the typical high distillate low sulphur crudes such as Forcados, but also a heavy high sulphur high residue crude oil such as Al Shaheen crude (Qatar) to benefit from its low price while using the conversion units for major upgrade of the yields.

These 2 crudes, Forcados and Al Shaheen are merely representations of crudes that typically represent qualities that will have to be used in the refinery for optimal performance. Crude oil buying, choice optimisation and mode of refinery unit operation is a sophisticated process that requires professionals such as traders, schedulers, planners and optimisation software all working together for the best performance. It is a continuous process to review the best route for the refinery every month, week or even every day of a week.

2.4.2 Refinery Configuration and Operation

Crude Oil Distillation Unit (CDU)

The new Crude unit will be designed for 100.000 barrel per day and is already described in detail under Scenario 3 item 2.1.

The existing 33000 barrel /day CDU will be in operation in this scenario. Its function is the provision of extra distillation capacity to meet the 6.0 million ton/year demand.

CDU and Vacuum Unit are relatively modern with the 33000 barrel/day CDU entirely overhauled and rebuild in 1999. Preferential feedstock is the for Bitumen classified crude oil Arab Light and added Al Shaheen crude which is also very likely a Bitumen production acceptable crude oil, although this needs to be verified.

The existing CDU is made more efficient with the adaptations as described in Scenario 2.

Total primary distillation is then 133.000 barrel/day or 6.0- 6.5 million ton refined product per year (depending on shutdown periods in the year for the existing and new ERL units).

Assumed is a total of 330 days for refinery operation, leaving one month as non operative for desired short shutdowns that will inevitably occur in a more sophisticated new build refinery where start-ups may be more time consuming and also will require more frequent adjustment in operating parameters. The 330 days is however a pessimistic estimate and is in reality much closer to 360 days per year with a good working unit complex following construction by experienced engineering companies and run by qualified operators.

As other units are added in this Scenario, the Merox unit capacity as described in scenario 3 will not be needed for Kerosine desulphurisation here.

Vacuum Distillation Unit (VDU)

The existing VDU from the old ERL complex will remain in operation as the preparation unit for Bitumen manufacture. Its small size will be ideal to support the dedicated feedstock to the Bitumen blowing unit as is originally designed in today's ERL setup. The light Vacuum gasoil remains a good blend stock for distillates in particular after hydro treatment.

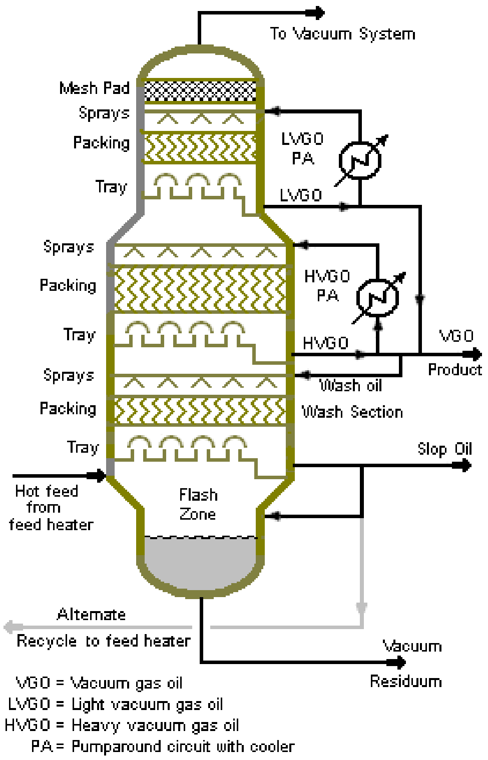
In addition to this very small operation there will be a new Vacuum Distillation Unit (VDU), designed to produce Vacuum Gasoil fractions for the Hydrocracker and its bottom product Vacuum Residue which will be feedstock for the Thermal Cracker Unit.

This VDU will be designed for all Atmospheric residues from the chosen crude oils produced in the two CDU's (33 and 100 mbpd units)

The capacity based on a combination of the 4 crude oil types and targeted to be around 45.000 barrel/day. Size is difficult to be exact since each crude oil will have a different quantity of atmospheric residue yield. Size does not have a large impact on the cost and therefore it is better to just oversize instead of underestimate the unit.

Most modern VDU's all are build to be close to the CDU for minimal intermediate storage and loss of efficiencies between the CDU and the VDU furnace. Typical VDU construction will include:

- Main Vacuum fractionator with a minimum of 4 packed trays, allowing recovering Lubricant type feedstock, beside a light and heavy Vacuum gasoil stream.
- Ejectors and condenser to reach levels inside the unit of 10-20 mm HG pressures.
- Feedstock pipeline direct from Crude unit to Vacuum unit reboiler to minimise energy use. The direct fuel consumption of a modern high-vacuum unit is approximately 1% on intake.
- An atmospheric residue reboiler furnace both gas and liquids fired.



At the place where the heated feed is introduced in the vacuum column - the flash zone - the temperature should be high and the pressure as low as possible to obtain maximum Vacuum Gasoil yield. The flash temperature is restricted to about 420 ^{0}C, in view of the cracking tendency of high-molecular-weight hydrocarbons. Vacuum is maintained with vacuum ejectors and /or with liquid ring pumps. Lowest achievable vacuum in the flash zone is in the order of 10 mbar in this Scenario as there will be conversion units that use the produced Vacuum Gasoil's.

Vacuum distillation columns (as in the drawing) typically used in oil refineries have diameters ranging up to about 14 meters (46 feet), heights ranging up to about 50 meters (164 feet), and feed rates ranging up from 1.000 (7000 barrels per day) to about 25,000 cubic meters per day (170,000 barrels per day).

The new 45.000 barrel/day VDU main function in this Scenario 4 is to produce good quality Vacuum Gasoil's and Vacuum Residues for further upgrading in the Hydrocracker to distillates and in the Thermal Cracker to distillates and Furnace Oils.

New Continuous Regenerating catalytic Reformer

This unit is discussed in detail in Scenario 3. The same size unit is used in this scenario. All descriptions made are applicable for this scenario as well.

One aspect of CCR Platformer is the production of Hydrogen. In a typical CCR the hydrogen output is 10% wt when performing to a Platformate of 100 RON octane.

This hydrogen can be used as a refinery fuel as happens today in ERL, but its main and more appropriate destination is to be used as feedstock in Hydrodesulphurisers and even Hydrocrackers.

Typically desulphurisation requires 1-1.5% wt Hydrogen, which means that a CCR can be 6.7 times smaller in size than a desulphuriser for hydrogen balancing purposes. In this setup a 5.000 barrel day CCR can produce sufficient hydrogen for a 35.000 barrel day Hydrodesulphuriser.

The design in this scenario is for a similar size CCR as in scenario3 despite the somewhat larger volume of Heavy Naphtha produces from both CDU units. However the volume of

Gasoline's produced is already in surplus and there is no requirement for more. Also the export of Gasoline to Singapore markets and other locations will cost the freight of a 25000 ton vessel and will offset almost all economics advantage of producing more gasoline. Instead the mode of operation for this scenario is set to produce more (light) kerosene and white spirits that not only have a higher value but also do not require specific capacity other than the CDU.

Isomerisation Unit

This Scenario will use the same 5.000 barrel/day capacity and design unit that was fully described in Scenario 3.

Hydrocracker Unit

Increasing global demand for high quality diesel has driven technology development at a rapid pace to provide refiners with ever improving ways to meet the demand.

Among the motor fuels, on-road diesel and kerosene will exhibit the highest growth rates, about 3% and 2% per year respectively over the period 2006–2020. This is what we already see in Bangladesh. Along with this trend, motor fuel specifications continue to be tightened, pushing demand towards ultra-low-sulfur (50 ppm and less) high Cetane quality Diesel.

Hydrocracking, one stage or two stages, with or without recycle, is part of that latest technology.

All hydrocracking processes are characterized by the fact that in a catalytic operation under relatively high hydrogen pressure (80-200 kg/cm2) a heavy oil fraction is treated to give products of lower molecular weight and almost all sulphur and nitrogen removed.

There are two types of Hydrocrackers:

- The Vacuum Gasoil feedstock Hydrocracker. Sometimes referred to as 'Mild' Hydrocracker, which is incorrect as Mild points to the operating pressure and the resulting distillate yield. Operating conditions are 375-400 degree C temperature and 80-170 kg/cm2 pressure.
- The Resid Hydrocracker. These units are capable to convert heavy furnace type Fuel Oils into low sulphur Gasoil's and Diesels. Operating conditions are severe, ranging from 380-430° C temperature and 150-230 kg/cm2 hydrogen pressure. As a consequence these units are very expensive and relatively small scale dictated by the severe operating conditions.

For this study the Resid Cracker is not the right type, as Fuel Oil is required in the demand scenario and the economics of a Resid cracker weigh very much towards their very expensive construction costs. Residue Crackers are usually build where the demand for Fuel oils is very limited or nonexistent and removal of low value Fuel Oil by export is a costly alternative.

The Vacuum Gasoil feedstock based Hydrocracker is less costly and is equally capable to produce good quality Diesel and kerosene from Vacuum Gasoil. Most Hydrocrackers are of this type.

Hydrocracker Process Description

When the processing severity in a hydrocracker is increased, the first reaction occurring leads to saturation of any olefinic material present in feedstock. Next comes the reaction of desulphurization, denitrogenation and de-oxygenation. These reactions constitute treating steps during which in most cases, only limited cracking takes place. When the severity is increased further, hydrocracking reaction is initiated.

Hydrocracking covers a widely different range of output, ranging from propane butane or LPG, light and heavy naphtha production, to Jet Fuel and Diesel and luboil manufacture from deasphalted oils and selected atmospheric residues, on the other.

A particular feature of the hydrocracking process, as compared with its alternatives, is its flexibility with respect to product outturn and high quality of its products. In the areas where quantitative imbalance exists of lighter products, middle distillates and fuel, hydrocracking is a most suitable process for correction.

Moreover, the hydrocracker does not yield any coke or pitch byproduct: the entire feedstock is converted into the required product range, an important consideration in a situation of limited crude oil availability.

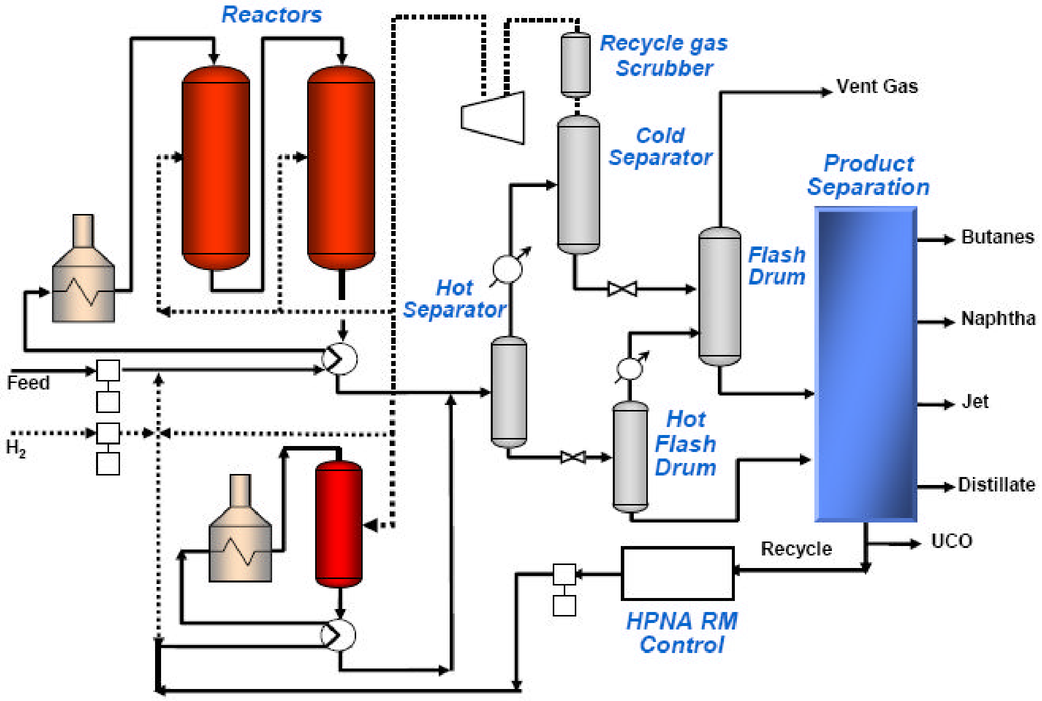
The first units date from World War II for supplying gasoline to Europe & America and catalysts used were natural clays while operating pressures were about 250 kg/cm2. Continuous developments in catalyst has resulted in lower pressure operation to produce desired quality products. At present more than 150 units are operating all over the world.

The development of the low-pressure catalytic reforming process, which produces relatively cheap, high quality hydrogen, has continued substantially to the economic viability of hydrocracking. On the whole, hydrocracking can handle a wider range of feedstock than catalytic cracking, although the latter process has seen some recent catalyst developments which narrowed the gap. There are also examples where hydrocracking is complementary rather than alternative to the other conversion process; an example, cycle oils, which cannot be recycled to extinction in the catalytic cracker, can be processed in the hydrocracker.

Most vacuum gasoil feed hydrocrackers use fixed beds of catalyst with down flow of the heavy gasoil in either one large or two smaller reactors.

A typical TWO-STAGE Process design consists of a first-stage whereby the feed is hydro treated and hydrocracked using catalysts especially designed catalysts for the respective duties.

The first-stage effluent is then separated into gaseous and liquid streams followed by fractionation of the liquid effluent into products and unconverted oil. Unconverted oil is recycled to the second-stage hydrocracking reactor. The second-stage hydrocracks the unconverted oil so that overall conversion from the unit can be as high as 100%.



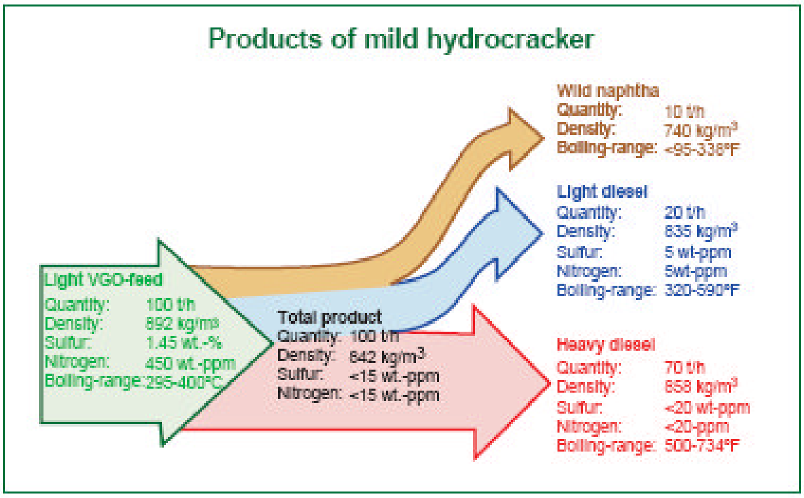
Courtesy UOP: **Two-Stage Unicracking Flow Scheme.**

Most Vacuum Gasoil Hydrocrackers in Europe and Asia aim for maximum distillate conversion but the process is flexible by adjusting temperature and pressure and type of catalyst; (low or high Zeolite content in the catalyst).

When the treating step is combined with the cracking reaction to occur in one reactor, the process is called a SINGLE-STAGE Process.

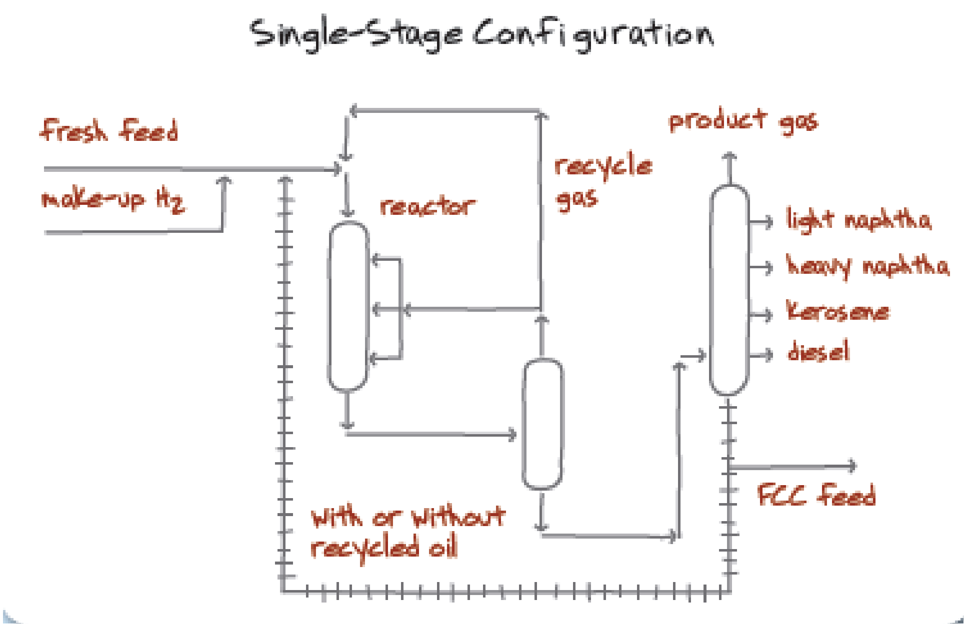
Mild Hydrocracking uses a single stage process at moderate severity conditions (70-120 kg/cm2 pressure). In this simplest of the hydrocracker configuration, the lay out of the reactor section generally is a single reactor unit operating under moderate conditions. This configuration will find application in cases where only moderate degree of conversion (50%) is required.

A typical feed and yield pattern from a Mild Hydrocracker is summarized in the presentation below. The (heavy) Diesel fraction is a proper motor fuel, but will be less in driving quality than a fully hydrogenated fraction.



Source: Schwedt Mild Hydrocracker

A further step in hydrocracking options is a Single stage process + bottom product recycle, which should be considered to reach full conversion to light distillates, but with a reduced capacity as a consequence.

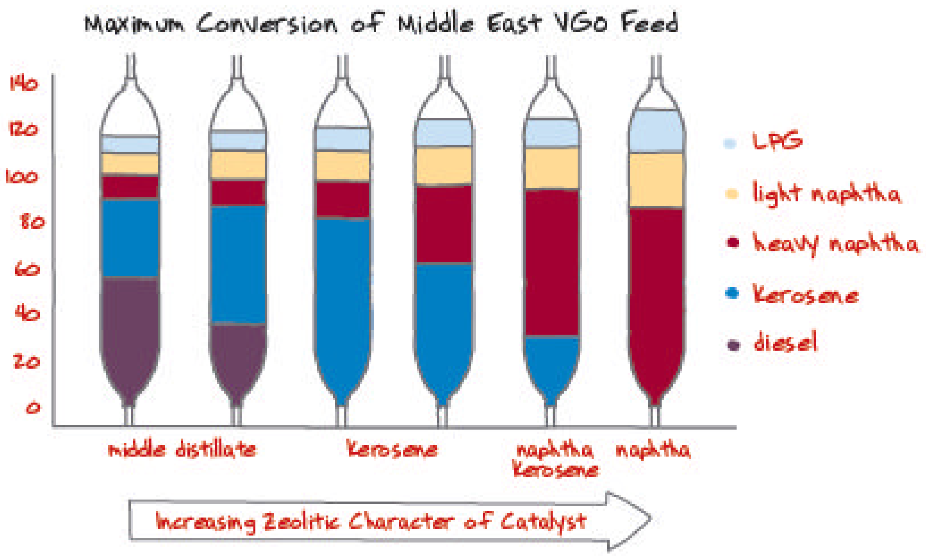


Source: Chevron Lummus

An example is the production of middle distillates from heavy distillate oils. The catalyst used in a single-stage process comprises a hydrogenation and desulphurisation function in combination with a strong cracking function that includes a typical 20-25% recycle stream under more severe conditions (above 150 kg/cm2) than in the Mild Hydrocracker.

Recycle of the bottom reactor streams will absorb some of the overall capacity if 100% conversion to distillate is required. The main reactor will convert recycled vacuum gasoil into Diesel as if it was a two stage operation.

Chevron Lummus advises in their process advice on a flexible distillate yield that can be obtained from Vacuum Gasoil (VGO), schematic presented as:



Source: Chevron Lummus

These yields in numeric form will be used as part of the overall yield performance in this scenario.

Output %wt		Intake %wt	
LPG	2.0%	Vacuum Gasoil	100.0%
Light Naphtha	6.0%	Hydrogen	2.5%
Heavy Naphtha/Spirits	7.0%		
Kerosene's (SKO and Jet Fuel)	22.0 %		
Diesel	57.0%		
Hydrowax (Fuel Oil)	3.8%		
H2S refinery gas	2.2%		
Cons /losses	2.5%		
Total	102.5		102.5%

Nearly all major constructors and major oil company have their own research and design for Hydrocrackers.

- GOFining — Exxon Research & Eng.
- Ultracracking — British Pet. Amoco
- Shell — Shell Global Solutions Center
- BASF-IFB — BasF, Anilin, IFP, Axens
- Unibon — UOP, LLC,

- Isocracking/ H-oil Chevron Lummus
- Unicracking UOP

Although it is not normal practice to promote designers at this stage, we will adopt the Chevron Lummus Two Stage process or the SSREC single stage + recycle process, also as CL has advised us on this particular Scenario (See Appendix).

Other designs from Shell Global Solutions and Axens confirm the CL advised yields in general although circumstances in operating conditions change for each design. Hydrocrackers are 'tailor made' to the specific function in a refinery and designs cannot be applied as a general valid yield indication or expectations.

Hydrocrackers are costly units, due to the severe operating conditions, the complexity of the reactor internals and the hydrogen compressor bank. As a rule of thumb construction cost are between 7000 and 9000 $ per barrel capacity. However the upgrading that takes place by the Hydrocracker operation is significant.

Platts Singapore Diesel over the observed period is 695 $/ton and Fuel Oil 438 $/ton, or a value difference of 257 $/ton (equivalent to 35 $/barrel on fuel oil feed) The Hydrocracker contributes almost 100% to this upgrade by conversion of atmospheric residue which is otherwise a Fuel Oil into high quality Diesel/Kero and is among all refinery units by far the highest upgrade contribution unit and payout of the investment is relative to other units still remarkably fast, despite the high investment costs.

For an extreme high distillate oriented demand as is the case for Bangladesh, the introduction of a Hydrocracker is a perfect means to alter the production yield from Fuel Oil into very low sulphur content Distillates.

For this Scenario 4 a 20.000 barrel/day Hydrocracker capacity will be assumed.

Hydrogen Unit

The Hydrocracker needs a supply of 1.5-2.3% Wt of pure Hydrogen to enable the process to work. Hydrogen is produced from hydrocarbons, preferably from Methane or Natural Gas as it has the highest quantity of Hydrogen attached to the carbon. However propane and butanes and naphtha can be used with almost equally good output of hydrogen.

Hydrogen is usually produced by the steam reforming of natural gas. At high temperatures (700–1100 °C), steam (H_2O) reacts with the help of a nickel based catalyst with the methane (CH_4) to yield syngas. The heat required to drive the process is generally supplied by burning some portion of the hydrocarbon gas. http://en.wikipedia.org/wiki/Image:Hydrogen.from.Coal.gasification__tampa.jpgAdditional hydrogen can be recovered from the carbon monoxide (CO) through the lower-temperature water gas shift reaction, performed at about 130 °C. In a last stage Hydrogen is purified to above 98% with a Pressure Swing Adsorption (PSA) unit.

PSA is a technology used to separate the hydrogen from a mixture of other hydrocarbon and nitrogen/carbon oxide gases under pressure according to the molecular characteristics and affinity for an adsorbent material. It operates at near-ambient temperatures. A dedicated catalyst or mol sieves such as Zeolite is used to preferentially adsorbing the hydrogen gas at high pressure. The process then swings to low pressure to desorb the adsorbent material.

The process description of a Hydrogen unit was described in detail in the Assessment report since ERL has a very small unit which has been shutdown since a few years.

However with a 20.000 barrel or 2850 ton/ day Hydrocracker, the requirement for Hydrogen at 2% on 100% VGO intake is almost 60 ton/day, leaving some hydrogen for supplementing the feed to the Hydrodesulphuriser unit.

ERL's current unit produces less than 5 ton per day which is by far not sufficient. This small unit is best to leave on standby, or use as additional supply of hydrogen for the new Hydrodesulphuriser in case of a relatively high degree of high sulphur crudes in the base slate.

Hydrogen units are usually integrated with the Hydrocracker and can therefore operate almost as stand alone without being dependent on the hydrogen production from the CCR Platformer, which in this scenario is dedicated for the hydrodesulphurisation unit (to be discussed).

Hydrodesulphurisation and Amine Units

In this Scenario 4 there is the introduction of the requirement for low sulphur content in Kero and Diesel. The regional specification varies depending on legislation, rural or city and overall environmental situation.

The tendency is reduction to just a few ppm sulphur in all motor fuels. Europe and the United states now limit the sulphur in Diesels to 50 ppm and will impose further reduction to 10 ppm in the near future.

The Southern Asian and Far Eastern Region now adopts in general levels at and below 500 ppm sulphur (=0.05% wt) for distillates and 100 ppm (=0.01% wt) or below for gasoline's.

For Bangladesh the policies for environmental requirements are still under discussion, therefore for scenario 4 assumed will be a sulphur content of 350 ppm in Distillates and 100 ppm in Gasoline's. This is also reflected in the regional international oil product markets in Singapore, China etc.

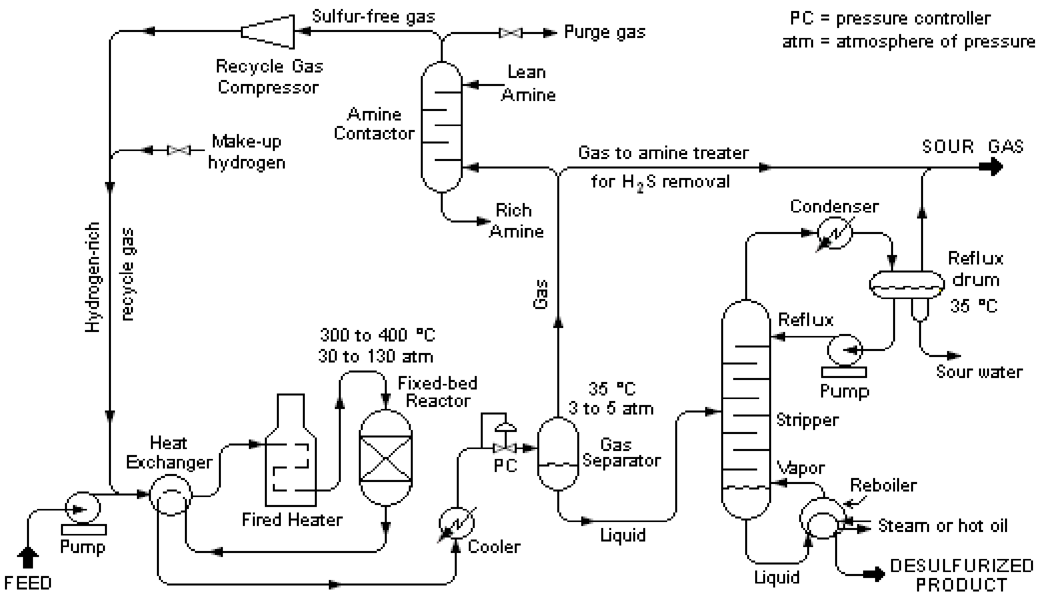
Removal of sulphur can only be done in a hydrotreater unit. There are alternatives such as Merox, but these simple units use oxidation of sulphur as a neutralisation and do not as such remove the sulphur but just convert sulphur in a less harmful compound. Also Merox units cannot convert large quantities but remain limited to relatively small volumes.

The main method is Hydro treatment, or Hydrodesulphurisation.

A Hydrodesulphuriser works quite similar to a Hydrocracker but at very moderate operating conditions. The unit just desulphurises, removes sulphur, but does not initiate any further Hydrocracking reactions. The hydrodesulphurization processes include facilities for the capture and removal of the resulting hydrogen sulfide (H_2S) gas. The hydrogen sulfide gas is then subsequently converted into the byproduct elemental sulfur.

The actual hydrodesulphurization reaction takes place in a fixed-bed reactor at temperatures ranging from 300 to 400 °C and elevated pressures ranging from 30 to 130 kg/cm2 (atmospheres) of absolute pressure, typically in the presence of a catalyst consisting of an alumina base impregnated with cobalt and /or molybdenum.

The image below is a schematic depiction of the equipment and the process flow streams in a typical refinery HDS unit.



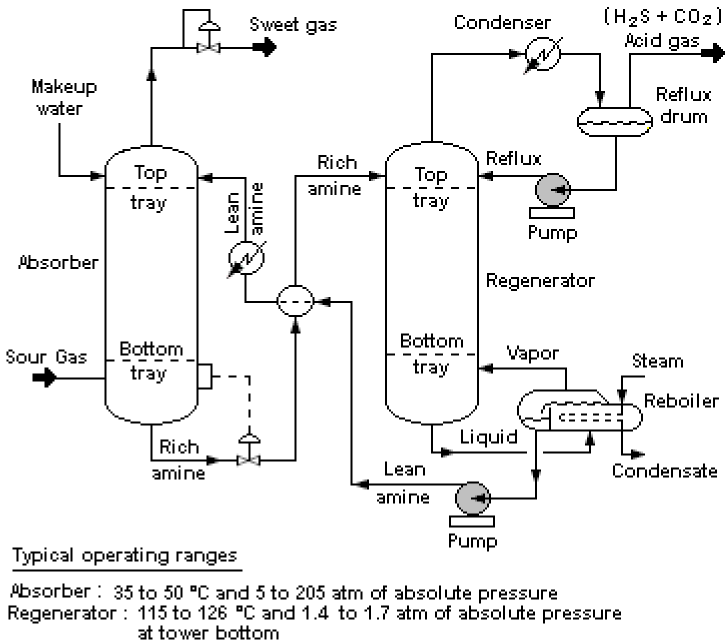
Courtesy GJK: Schematic diagram of a typical Hydrodesulphurization (HDS) unit in a refinery

The liquid feed (at the bottom left in the diagram) is pumped up to the required elevated pressure and is joined by a stream of hydrogen-rich recycle gas. The resulting liquid-gas mixture is preheated by flowing through a heat exchanger. The preheated feed then flows through a fired heater where the feed mixture is totally vaporized and heated to the required elevated temperature before entering the reactor and flowing through a fixed-bed of catalyst where the hydrodesulphurization reaction takes place.

The hot reaction products are partially cooled by flowing through the heat exchanger where the reactor feed was preheated and then flows through a water-cooled heat exchanger before it flows through the pressure controller (PC) and undergoes a pressure reduction down to about 3 to 5 atmospheres. The resulting mixture of liquid and gas enters the gas separator vessel at about 35 °C and 3 to 5 atmospheres of absolute pressure.

Most of the hydrogen-rich gas from the gas separator vessel is recycle gas which is routed through an integrated separate unit where the H2S gases are separated from the Distillate. This is the Amine Absorber and regenerator which is a part of the Hydrodesulphuriser unit and removes the acid gases by an aqueous amine solution usually Deethanolamine (DEA).

A typical amine gas treating process includes an absorber unit and a regenerator unit as well as accessory equipment. In the absorber, the down flowing amine solution absorbs H_2S and carbon dioxides (CO_2) from the up flowing sour gas to produce a sweetened gas stream (i.e., an H_2S-free gas) as a product and an amine solution rich in the absorbed acid gases. The resultant "rich" amine is then routed into the regenerator which is build as a stripper with a reboiler to produce regenerated or "lean" amine that is recycled for reuse in the absorber. The stripped overhead gas from the regenerator is concentrated H_2S and CO_2.



Courtesy GJK: Process flow diagram of a typical amine treating process used in industrial plants

H_2S gas is lethal even in very low (smaller than 30 ppm) concentrations. The next required step is complete destruction of H_2S gas into pure sulphur in a Sulphur Recovery Unit (SRU) which will be discussed later.

In scenario 4 there will be one central approx 300.000 ton/year amine plant that will also serve the H_2S stripping from other units such as the CCR Platformer Hydrotreater and the Hydrocracker's Hydrogensulphide gas production.

Assumed in Scenario 4 is a 50.000 barrel/day capacity Hydrodesulphuriser that will take all distillates (Kero and Diesel) from the Crude oil Distillation unit as well as a large portion of the aromatic Diesel stream from the Visbreaker and Thermal Cracker (to be discussed).

The Visbreaker and in general any thermally cracked hydrocarbon produce an unsaturated distillate that will discolor and react with oxygen if left untreated. Hydrodesulphurising these streams will not only remove sulphur but also will saturate the distillates into a good quality high Cetane Diesel. The process also removes unwanted odours which will benefit overall quality at service stations as well as limiting undesired spoiled egg stench from refinery storage tanks vents.

Thermal Cracker and Visbreaker Units

The new 45.000 barrel day Vacuum Unit (as described in 2.2) produces as bottom product the Vacuum Residue.

With the typical atmospheric residue composition from the Crude Oil Unit as feedstock for the Vacuum unit the expected intermediate output will be on average 50% Vacuum Gasoil and 50% of Vacuum Residue. The percentages will vary entirely depending on the degree of vacuum and the quality of the feedstock but in general these deviations will be small.

As a result the availability of Vacuum Residue will be at least 20.000 barrel per day and likely somewhat more if heavier crudes are run or the percentage of heavier crude increases in the base slate.

Vacuum Residue is high in viscosity, much higher than the commercially acceptable 380 CST Fuel Oil as used in furnaces, ships engines etc. One way to correct viscosity is by blending with low viscosity distillate, but a Visbreaker is the appropriate method for viscosity reduction and does as such not require the use of distillate to be blended and thus downgraded into the Fuel Oil pool.

The existing 10.000 barrel/day ERL Visbreaker is in today's operation using atmospheric residue as feedstock. It is a fairly modern and energy efficient processing unit with the purpose is to reduce the quantity of residual atmospheric oil, long residue produced in the Crude Oil Distillation Unit and to increase the yield of more valuable distillates and Diesel.

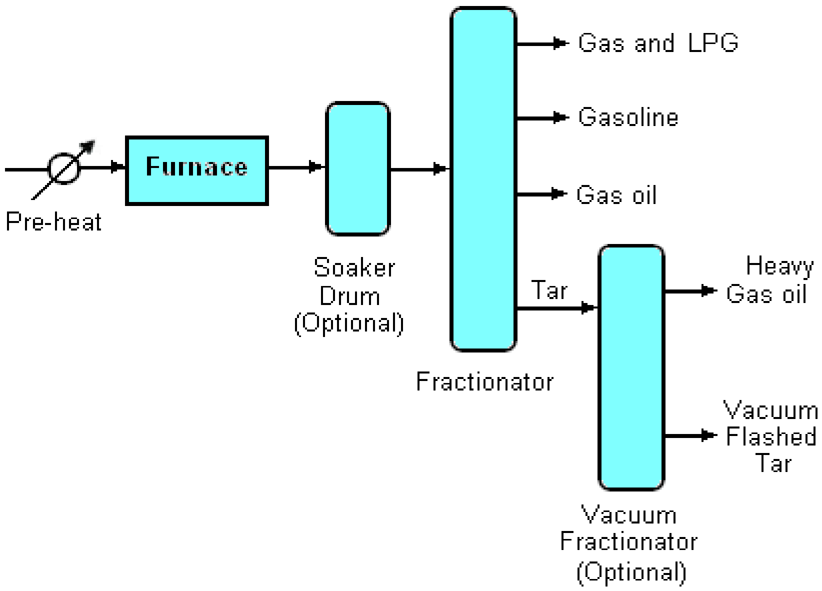
A Visbreaker thermally cracks large hydrocarbon residual fuel oil molecules by heating the oil in a furnace to reduce its viscosity and to produce small quantities of light hydrocarbons. The process name of "Visbreaker" refers to the fact that the process reduces (i.e., breaks) the viscosity of the residual oil. The process is non-catalytic. Thermal cracking is a more severe version of the same process leading to more production of light products but more heavy and dense residual fuel.

Thermal cracking and visbreaking is a simple process compared with Platforming and Hydrocracking.

The process only requires heat and some low pressure to initiate cracking and the investment cost in Thermal Crackers and Visbreakers is low compared to the more sophisticated cracking processes. Over design of capacity is therefore hardly requiring extra funds once the basic design is made.

Cutting down to the most essential elements of a Thermal Cracker is the furnace, the soaker drum and the fractionator section. All light products from these units are highly aromatic and part will be used to 'stabilize 'the Fuel oil.

Some thermal crackers add pressure to break the long chain hydrocarbons thereby improving the distillate yield, but this also promotes the formation of cokes in the furnace tubing.



Typical design of Thermal Cracker/Visbreakers.

The Visbreaker yields of the various hydrocarbon products will depend on the "severity" of the cracking operation as determined by the temperature the oil is heated to in the Visbreaker furnace. At the low end of the scale, a furnace heating to 425 °C would crack only mildly, while operations at 500 °C would be considered as very severe. Arabian light crude residue when visbroken at 450 °C would yield around 76% (by weight) of tar, 15% middle distillates, 6% naphtha and 3% gas and LPG.

Visbreaker tar can be further refined by feeding it to a vacuum fractionator. Here additional heavy gas oil may be recovered and routed either to catalytic cracking, hydrocracking or other thermal processes like propane deasphalting on the refinery. The vacuum-flashed tar is then routed to fuel oil blending for final viscosity correction

The ERL Visbreaker will in this scenario run on Vacuum residue instead of long atmospheric Residue. There will be very minor changes in the adaptation to vacuum residue processing and mainly in the residence time through the furnace heating coil.

With the ERL Visbreaker capacity at 10.000 barrels day, there will be a need for a new small 15.000 barrel day Thermal Cracker unit. Thermal Crackers are like Visbreakers but are constructed to gain more distillate from the process by lengthening the residence time of the high temperature feedstock and the duration of the actual cracking process.

Cracking is taking place in the furnace heater and immediately thereafter in a Soaker Unit which controls the degree of cracking by altering residence time. Soaker drums require far less frequent attention but their being taken out of service normally requires a complete halt to the operation.

A Thermal Crackers process design is almost identical to a Visbreaker, but with minor changes of which the soaker drum unit's the most important one.

The severity of Visbreaker operation is normally limited by the need to produce a Visbreaker tar that can be blended to make a stable fuel oil. Stability in this case means the tendency and degree of a fuel oil to produce asphaltenic sediments when stored. These sediments are undesirable as they can quickly foul the filters of pumps used to move the oil necessitating time-consuming maintenance. The normal way to prevent asphalthenes from forming is the addition of some aromatic compounds such as Visbreaker gasoil, which will restore the aromaticity balance in the fuel oil which in turn will keep the Fuel Oil stable from forming asphalthenes. Stability of fuel oil is assessed using a number of proprietary tests (for example "P" value and Shell Hot Filtration tests).

Visbreakers and in particular Thermal Crackers are also major contributors to the upgrading value in any refinery. With a conversion in a Thermal cracker of 35% (Visbreaker at 25%)of the Vacuum Residue as Vacuum Resid Fuel oil in to Distillate means a contribution per 100% Feedstock of 90 $/ton or 12 $/barrel conversion. And this does not account for the saving in blending of low viscosity distillate into the Fuel oil pool. Both the Thermal Cracking as does the Visbreaker also reduce the viscosity of the remaining Fuel Oils.

The payback time for Thermal crackers is usually within a few years; also as the unit investment cost is relatively low, between 3000 and 4000 USD per barrel capacity compared with other units like the CCR and Hydrocracker.

Sulphur Recovery Unit

The Hydrocracker, Naphtha Hydrotreater (part of the CCR Platformer) and the Distillate Hydrodesulphuriser all produce concentrated H_2S gases as a result of their respective processes. H_2S is a sour gas and therefore corrosive to burn in furnaces. H_2S is also a deadly gas for all living beings even in very small concentrations.

In Scenario 4 with the capacities discussed the H_2S needs to be converted into pure sulphur. Sulphur has a value in the petrochemical and fertilizer industry, while H_2S as such has a negative value to the environment when it leaves the amine treatment unit.

Hydrogen sulphide gas is converted into 95% pure sulphur in a Sulphur recovery unit, also called a Claus unit, which is the most common and most efficient process.

The Claus process has become the industry standard. It is a multi-step process that recovers sulfur from the gaseous hydrogen sulfide. Gases with an H_2S content of over 25% are suitable for the recovery of sulfur in straight-through Claus plants while alternate configurations such as a split-flow set up or feed and air preheating can be used to process leaner feeds.

The Claus technology can be divided into two process steps, thermal and catalytic.

In the thermal step, hydrogen sulfide-laden gas reacts in partial combustion with oxygen at temperatures above 850 °C such that elemental sulfur precipitates in the downstream process gas cooler. Usually, 60 to 70% of the total amount of elemental sulfur produced in the process is obtained in the thermal process step.

The main portion of the hot gas from the combustion chamber flows through the process gas cooler and is cooled down such that the sulfur formed in the reaction step condenses. The heat given off by the process gas and the condensation heat evolved are utilized to produce medium or low-pressure steam. The condensed sulfur is removed at the gas outlet section of the process gas cooler. The whole process is a net contributor to the power and heat generation and is important for the total refinery efficiency. Usually a SRU contributes for 20 % of the refinery steam production.

The Claus reaction continues in the catalytic step with activated alumina or titanium dioxide, and serves to boost the sulfur yield. The hydrogen sulfide (H_2S) reacts with the SO_2 formed during the in the thermal phase occurring combustion in the reaction furnace, and results in gaseous, elemental sulfur. This is called the Claus reaction:

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O$$

The typically recommended operating temperature of the first catalyst stage is 315°C to 330°C . The high temperature in the first stage also helps to hydrolyze Carbon oxides and carbon sulphide compenents, which are formed in the furnace and would not otherwise be converted in the modified Claus process.

The catalytic conversion is maximized at lower temperatures, but care must be taken to ensure that each bed is operated above the dew point of sulfur. The operating temperatures of the subsequent catalytic stages are typically 240°C for the second stage and 200°C for the third stage .

In the sulfur condenser, the process gas coming from the catalytic reactor is cooled to between 150 and 130°C. The condensation heat is used to generate steam at the shell side of the condenser. Using two catalytic stages, the process will typically yield over 97% of the sulfur in the input stream. Over 2.6 tons of steam will be generated for each ton of sulfur yield.

Estimated capacity of the Sulphur Recovery for Scenario 4 refinery is 60-80 ton sulphur/day.

Power and Electricity Generation

The refinery as described and operated in Scenario 4 is a sophisticated refinery. The addition of the Hydrocracker, Naphtha and Distillate Hydrotreaters, a Thermal Cracker , Sulphur Recovery and Amine units all require electricity and some steam. Hydrogen compression demands a high delivery of electricity.

Electricity demand for Scenario 3 was an estimated 12 MWh, but Scenario 3 was a basic unit configuration, the CDU and CCR with Isomerisation aimed at the production of primary distilled volumes.

Scenario 4 will require much more electricity and needs a very reliable resource as in particular the Hydrocracker and Hydrodesulphuriser cannot be uncontrolled shutdown without damage to these units because of an unscheduled loss of power. Usually Hydrocrackers have their own dedicated electricity generation for that reason with a backup generator on standby.

The exact electricity demand is difficult to estimate since hydrogen compression and the compressor methods differ between designers. Combined Heat and Power for the increased demand is the natural solution as otherwise cost of conventional steam generated electricity would be very high and well above the industry norm. The viability of CHP (the utilization factor), especially in smaller CHP installations, depends upon a good base load of operation, both in terms of an on-site electrical demand and heat (for steam production) demand. In practice, an exact match between the heat and electricity needs rarely exists. A CHP plant can either meet the need for heat or be run as a power plant with some use of its waste heat. The latter being the least advantageous in terms of its utilization factor and thus overall efficiency. The viability can be greatly increased where opportunities for Trigeneration exist. In such cases the heat from the CHP plant is also used as a primary energy source to deliver cooling by means of an absorption chiller. (The refrigerator principle) beside heating for power and steam and the direct electricity generation.

CHP is most efficient when the heat can be used on site or very close to it. In Scenario 4 all units will be very close together to minimize loss in pressures, heat and process residence time. Overall efficiency is reduced when the heat must be transported over longer distances. This requires even for Bangladesh insulated pipes, which are expensive and inefficient; whereas electricity can be transmitted along a comparatively simple wire, and over much longer distances for the same energy loss.

Based on an average continuous 24 hour utilization the minimum generation capacity needed is estimated around 30 MWh for Scenario 4. This excludes the required backup for the Hydrocracker and Hydrodesulphuriser which is estimated to be around 7 MWh capacity.

Other Utilities

Despite the introduction of 4 major new units there will be no additional requirements for cooling capacity, process water, or oil/water separation as described in Scenario 3.

These new units are all latest technology and will even reduce the need for these facilities.

One suggestion is to consider a bio treatment facility instead of the extension of oil/water API separation which is currently in place. This is a more environmentally friendly approach to water/oil traces removal via biological or scavenger type cultures. Although the facility will need to be build, it also will produce methane gases that can be used to replace purchase of natural gas and is as a benefit and useful product from the bio system.

Necessary will be to invest in a new Flare stack. With the extra activity there will be more units that each produces refinery gases and liquids that may need to be flared in an emergency.

Also the current Flare is close to the units and is relatively low in height.

Proposed therefore is to build a new higher and larger capacity Flare, at a considerable further distance from the main units than the current flare, with a knock out drum and some gas/liquid recovery facility.

Summary of Scenario 4 Operating Units and Capacities	
Existing ERL Crude Distillation unit	33.000 bbl/day
New Crude Distillation unit	100.000 bbl/day
Existing Vacuum Distillation unit	4.000 bbl/day
New Vacuum Distillation unit	45.000 bbl/day
New Cont Catalytic Reformer (CCR)	5.000 bbl/day
New in CCR integrated Naphtha/Kero Hydrotreater	10.000 bbl/day
New Isomerisation Penex unit	5.000 bbl/day
Reactivated Hydrodesulphurisation Unit	1.700 bbl/day
New Hydrodesulphurisation unit	50.000 bbl/day
New Amine treatment unit	300.000 ton/year
New Two stage or SSREC Hydrocracker	20.000 bbl/day
New Hydrogen Plant	60 ton/day
Reactivated existing Hydrogen Plant	3 ton/day
Existing redesigned Visbreaker	10.000 bbl/day
New Vacuum Resid Thermal Cracker	15.000 bbl/day
New Merox unit (LPG)	100.000 ton/year
Sulphur Recovery Unit	80 ton/day
Existing Bitumen Blowing Unit.	70.000 ton/year
New CHP unit (3*10+1*7 MWh)	37 MW/h.
New RO water plant	400 t/hr
New Flare	

Units Shutdown:	
Existing Conventional Power plants	8 MW/h (as backup function)
Existing Semi Regenerative Reformer	1700 bbl/day

With this degree of refinery sophistication there will be differences in approach to the capacity configuration and also the ultimate design for the overall configuration. This also is influenced by the choice of crude oil in the base slate, mode of operation and the by the region and the refinery targeted product specifications.

Each Front End Engineering Design (FEED) company will have their own approach based on experience. The above discussed unit capacities in this study are therefore indications only and could differ by as much as 20% variation.

2.4.3 Supply and Demand Balance Scenario 4

In the previous scenario 3 almost 75 % of the total oil product demand was refined product. In scenario 4 with the construction of the larger new 100.000 barrel day Crude Unit, and the existing ERL 33.000 barrel day Crude Unit a total of 6.0 million ton oil products is produced, and with the emphasis on new Distillate upgrade type of configuration the maximum possible distillate yield is obtained and minimises the imbalances left.

There is still the need to balance the products as the produced refined product yield is not equal but now very close to the (unique distillate driven) demand yield.

Total demand equals total supply by the Scenario 4 refinery **so there is no net importation,** but just imbalances.

Demand remains driven by Distillates, Kero and Diesel, but all of Kero, Jet Fuel and 3 million ton Diesel distillates is refined out of the 3.5 million ton demanded.

There is some import 400.000 ton/year of Furnace fuel oil as a result of the conversion by the Hydrocracker and Thermal Cracker of Fuel Oil components into Distillates. Jet fuel is again all produced now by ERL and the configuration could even produce more but excess kero potential is used for Diesel blending which is made possible by the presence of the Hydrocracker and Hydrodesulphuriser which not only produce a very low sulphur quality but also improved the Cetane Number to well above 51.

LPG is now in surplus by some 35000 tons and can either be exported, or sold on the domestic market if the private parties now importing and supplementing will decide to avoid competition from refinery supplied excess LPG.

The main import is still Diesel but for just 550.000 ton per year or 15 % of the total Diesel demand.

Imbalances are, compared to the total refinery production, very minimal. The lightest products such as Light Naphtha and Gasoline's remain the prime export products and despite the cost of transportation there will be the benefit from the Singapore market prices.

On a daily average basis import and export cancel each other out. Imports are just 2.600 ton of Diesel and Furnace Oil while exports are for Naphtha, Gasoline's and some Kero.

In the previous scenario total Net import was around 4200 ton/day and a total movement of approx 7400 ton/day, while in this scenario there is a 0 balance achieved, with just 4500 ton daily movement of net balancing imports and export.

All net import is in crude oil, which like in Scenario 3 will all be imported via the SPM facility at the Kutubdia Anchoring point. Chittagong port therefore has only the outgoing movement of river barges and tankers to the inland depots and of course the net import and export movements from the refinery production.

Bangladesh supply and demand					Scenario 4	
In Kton	Petroleum product Demand		Refinery output		Product Import (neg =export)	Import per day
LPG	50,0	0,8%	84,9	1,4%	-34,9	-0,1
Naphtha			199,8	3,3%	-199,8	-0,5
Premium	125,0	2,1%	201,3	3,4%	-76,3	-0,2
Regular	125,0	2,1%	300,0	5,0%	-175,0	-0,5
Spirits	10,0	0,2%	136,9	2,3%	-126,9	-0,3
Kero	300,0	5,0%	443,5	7,4%	-143,5	-0,4
Jet Fuel	350,0	5,8%	383,6	6,4%	-33,6	-0,1
Diesel	3 500,0	58,3%	2954,9	49,2%	545,1	1,5
Jute/other oil	50,0	0,8%	69,1	1,2%	-19,1	-0,1
Furnace oil	1 370,0	22,8%	965,4	16,1%	404,6	1,1
Lubricants (import)	20,0	0,3%	0,0	0,0%	20,0	0,1
Bitumen	100,0	1,7%	103,9	1,7%	-3,9	0,0
Refinery own used Fuel			156,8	2,6%	-156,8	
TOTAL	**6 000,0**	**100%**	**6 000,0**	**100,0%**	**0,0**	**0,0**
Murban			960,0	16,0%		
Arab Light			1800,0	30,0%		
NGCondensate			240,0	4,0%		
Forcados			2400,0	40,0%		
Al Shaheen			600,0	10,0%		
Crude Oil			6 000,0	100,0%	6 000,0	16,4
Crude+Products					6 000,0	16,4

This is a realistic scenario for the almost total independence from imports with refined product capacity increase to meet target demand and with an important contribution from conversion facilities to upgrade value and product supply from the production of fuel oil into distillates. If these investments are made and the already in scenario 3 discussed different operating attitudes is implemented then this refinery operation will be more than sustainable in the long term with a positive net refiner's margin to meet the country demand as expected in 2015.

The dependency on importation of all sorts of refined product is just the balancing of the remaining surpluses and deficits, altogether less than 15% of the total demand. Scenario 4 will as a consequence have minimal trading results due to the small quantities involved (less than 5000 tons per day).

Instead the supply emphasis will be on crude oil trading and crude oil shipping to further improve the overall margin. In this refinery crude oil base slate there is the introduction of Al Shaheen crude (Qatar) as example of further crude oil feedstock diversification that is made possible by the refinery configuration.

2.4.4 Limitations to scenario 4

As discussed earlier in Scenario 3, this Scenario 4 assumes the construction and ready for operation of the Single Point Mooring facility in at least 17 m draft water to accommodate Suezmax vessels of 130-175.000 ton size with a minimum pumping capacity of 3000 Cubic meter per hour.

Crude oil runs for the combined CDU 133.000 barrel/day are now approx 16.500 ton per day up another 3000 tons compared to the 100.000 barrel operation in Scenario 3. All crude oil will be pumped to Chittagong crude oil storage to maintain uninterrupted runs.

At a SPM Capacity of 3000 cbm/hour minimum there will then on average 6 hours per day of continuous pumping from discharging vessels to shore, whether directly to Chittagong or preferably via intermediary buffer tanks somewhere on land near the SPM anchoring point.

In the unfortunate case where the Kutubdia Anchoring SPM project is delayed or otherwise postponed, there is a less attractive alternative offered whereby lightering at Kutubdia Anchoring again takes place but with proper 50.000 ton vessels which will then sail to the Sandwip channel with a draft of 11-12 meters. It will either discharge via a local SPM and connected for the short distance to the Chittagong shore and refinery complex or directly at a purpose build jetty stretched out 2 km into the sea from shore. A more detailed description of this alternative is given at the close of this Scenario 4.

Of course the cost of such lightering operation is mainly the lightering tariff; estimated at 4 USD/ton (0.54 USD/barrel) crude and the investment in the jetty or small SPM in the Sandwip channel. This is a far higher cost compared with the far more efficient Kutubdia SPM connected via a 75 km pipeline to Chittagong which 175 million USD investment will be recovered at a mere 0.16 USD/barrel charge. (included in the operating expenses).

Crude oil Supply Planning and Scheduling

The crude oils supplied will come from at least 5 different qualities: Arab light type for bitumen, heavy high sulphur crude like Al Shaheen for reducing crude oil cost while maintaining a good quality product output, Murban, the local Natural Gas condensates and the low sulphur/high distillate content type crudes.

Good forward planning is a must to prevent congestion at the SPM and at the crude oil storage tanks.

Like in Scenario's 3 there will be increased efforts and the need to charter Crude oil vessels in the right lifting windows and for the right loading terminals. Demurrages are expensive and need to be avoided. The Kutubdia SPM facility and pipeline connection to Chittagong is of overriding importance.

Crude Oil Storage

ERL current crude oil tanks have just enough capacity to maintain a run rate of 16500 ton/day with its 300.000 ton storage capacity. This is good for 18 days uninterrupted crude oil supply to the refinery.

However there are in this Scenario 4 at least 5 different crude oil types. Good refinery practice will use a prepared mixture from the day tank supplies but crude oil supply vessels will need to be stored initially in segregated storage to preserve the sulphur content and the typical qualities from Bitumen crudes.

This need will absorb half the available storage with most supplies arriving in 130-170.000 ton parcel sizes at the SPM.

ERL's current storage of just over 300.000 cbm is therefore a limitation and two new tanks each 50.000 cbm tanks are foreseen to be build to allow sufficient flexibility to run a variety of crude oils supplied by the optimum choice of vessel size.

Product Storage

Both ERL and the MI storage tanks together are considered for the refinery storage as was the case in previous scenarios. Where in Scenario 2 and 3 there was still a need for dedicated storage for import of products, this is not the case in Scenario 4. With the exception for some Diesel and Fuel Oil imports there is no significant import that requires storage tanks, nor is there a need for blending as all products are supplied from the refinery.

The refinery will have to change the service of its tanks to both increased rundown intermediary and finished product service, with pipeline bridges and corridors redesigned.

The overall (ERL and MI) product storage of 573.000 cbm is just acceptable for a 133.000 barrel day (16500 ton/day) crude run. This is a 35 day average period to hold all products.

Scenario 3 required more LPG storage and this will also be applicable here, as the current 2000 cbm total capacity are not sufficient to hold the LPG for longer periods or when emergencies arise if LPG offtake is interrupted.

It is recommended to build one other sphere of 2000 cbm capacity.

The other area is the storage dedicated to intermediate streams of distillates.

With much more Diesel oil produced in the CDU, Hydrocracker Hydrodesulphuriser and Visbreaker and Thermal cracker there is far more intermediate product that initially is kept segregated before blended into finished grades. This will require more tanks.

Daily distillate (Diesel and Kero) output is 10.000 tons and more than half of the total production. The refinery will need at least 3 more tanks of each 15.000 tons to store all the different distillate (intermediate) products and allow sufficient flexibility for blending and delivery to the inland depots product barges.

The same is applicable to the additional Thermal cracker unit, which will require its own feed tank and this would be a 30.000 ton tank to be build near the unit.

The available land for construction of units and tanks

The current ERL refinery site was sufficient to provide room for the CCR, Isomerisation and the new CDU in Scenario 3.

In Scenario 4 all new units; Vacuum unit, Hydrocracker, Hydrogen plant, Hydrodesulphuriser, Amine treatment and Sulphur recovery need to be considered for space as well. Then there is the larger CHP Gas turbines, and the LPG sphere, distillate and fuel oil storage additions.

As discussed current ERL is widespread build, and there is sufficient room to accommodate the CDU, CCR, CHP Gas turbine and Isomerisation Units by removing part of the buildings that occupy the site. Estimated area needed is 40.000 sq meters or 10 Acres.

Assumed is again a compact building design for the Hydrocracker, Hydrogen unit, Hydrodesulphuriser, Amine and Sulphur recovery, Vacuum unit and Thermal cracker. All together this will be at least another 250.000 square meter or 60 Acres.

Likely all of the buildings may have to be removed, and some of the spaces immediate adjacent needs to be purchased.

The 30 MWh CHP Gas turbines and enlarged RO unit do not require much space and can probably be built close to the existing power and water facilities with perhaps removal of part of the buildings there.

One of the objectives is to concentrate all new investment to benefit from the already present electricity, water and steam infrastructures.

2.4.5 Crude Oil Choice for this Scenario 4

The same crude oil types, Arab Light type for Bitumen quality manufacture, Murban type for general high sulphur 'easy to run' crude and low sulphur high distillate type such as Forcados (or similar) and of course the local produced Nat Gas condensate will be the basic feedstock slate in this Scenario 4.

With the ability to upgrade and destroy unwanted sulphur and remove aromatic components with the Hydrotreater and Thermal Cracker, this Scenario 4 refinery will have no problem to run heavy 25-28 API type of high sulphur crudes.

These crudes are relative cheap compared with the light 'easy to run' middle east crudes like Murban, Iranian light , Lower Zakum, Oman and Arabian light.

The reason for price differences is the inability of refiners to consider the heavy high sulphur crude for feedstock as their refineries are not capable to consider these crudes or not sophisticated enough build to obtain the value from upgrading fuel oil components that form the largest part of the Al Shaheen type heavy crudes in primary distillation.

Comparable crudes to Al Shaheen are Ratawi/Eocene, Kuwait, Iran Heavy and Arab Heavy all produced in the AG region.

Similar, but Low sulphur heavy and low API crudes are available, such as Duri, Widuri from Indonesia and Dar Blend from Sudan.

To illustrate the cost/value relationship Al Shaheen and Murban are compared in the table below. Striking difference is the yield for each and the (at actual Platts values) calculated gross refiners margins for each if individually run at the refinery configuration in Scenario 4.

API	**28.0**	**39.6**	**Platts Sing**
	%wt	**%wt**	**$/ton**
	Al Shaheen	Murban	
LPG	2.0%	1.6%	627
Naphtha	2.1%	7.7%	652
Premium Gasoline HOBC	4.8%	4.8%	721
Regular Gasoline MS	4.4%	4.4%	714
Spirits	1.4%	1.2%	730
Kero	6.4%	10.6%	735
Jet Fuel	11.9%	18.0%	735
Diesel	38.0%	40.8%	695
Jute/other oil	0.2%	0.2%	680
Furnace oil	23.9%	7.3%	438
Bitumen	1.4%	0.0%	488
Own cons/loss	3.5%	3.4%	
	100.0%	100.0%	
	$/bbl	**$/bbl**	
Refined value	86.54	87.10	
Crude oil cost Fob	76.53	80.36	
freight	2.00	2.00	
refiners gross margin	8.01	4.74	

The table clearly favours to run Al Shaheen crude oil, despite the lower API. Both crudes load in the AG and freight is assumed (almost) equal. This does not mean that Al Shaheen should be purchased, but the crude is cheap and is a good basis for upgrading. It is a mere indication of a crude oil that seems to fit in this Scenario very well. As pointed out there are many crude oils like Al Shaheen. Irregardless of the sophistication of a refinery, running heavy high sulphur crudes require good operatorship and good quality process engineers to be creative to optimise on a refinery base slate.

2.4.6 Product Qualities Scenario 4

Product quality changes in this scenario 4 to meet the standards in the region.

With the introduction of units aimed at destruction of sulphur, nitrogen, and aromaticity and other instabilities products can compete for their environmental impact with the lowest limits set by regional convention.

The larger crude runs and resulting volumes in Diesel and Kero can all be treated almost irregardless of the crude oil base slate composition.

Furnace oil sulphur content is the only specification that needs to be controlled by the quantity of Low Sulphur Crudes in the base feedstock.

There is now major desulphurisation of Kero and Diesel

Similar for Distillate quality, the Gasoline production from the CCR and Isom units have all been pre-treated in the new build integrated Naphtha Hydrotreater unit and sulphur will be far below 100 ppm, as per most accepted standards in the region.

Also benzene content in Gasoline will now be below 1% after the new CCR Platformer splitter and recycle of benzene rich light Platformate in the Isom Unit.

Heavy Fuel Oil sulphur will be at or just below 2.0 % in the base slate as used in this Scenario with 40% Forcados and 60% high sulphur crudes with Al Shaheen crude being the highest in sulphur content.

Key product test specifications

		ERL actual situation	Scenario 4	Target
Light Naphtha				
Paraffins	%vol	85		
Doctor test		Positive	Negative	
Lead	ppb	8	<1	
Vapour Pressure	KPa	84		
Gasolines unleaded				
Octane Research		95	95, 92, 88	
Benzene	% wt	5	<1	1
Sulphur	ppm	250	<50	100
Oxygenates	%wt	NA		
Aromatics	%wt	NA		
FBP	C	210		
Vapour Pressure	KPa	85	<85	
Jet Fuel A1				
Defstan 91-91**		no production	production	production
Kerosine household				
Distillation IBP	C	160	unchanged	
Smoke point	mm	20		
Flash point	C	40		
Sulphur	ppm	2850	350	350
Diesel				

Cetane Index		50	55	51
Sulphur	ppm	2800	350	350
Cloudpoint	C	NA		
Flashpoint	C	39	55	55
Furnace Oil				
Sulphur	%wt	3.5	2.0	2.0

The ability to produce on spec product will also benefit the easy and the value when product imbalances need to be traded in and out of the refinery. Off spec products do not collect the full value and contribute to more losses that will now be avoided.

2.4.7 Efficiencies in Scenario 4

In Scenario 4 there are further major efficiency improvements both in the refinery processing and the utilities compared with the previous scenarios.

But the introduction of 5 extra units, in particular the Hydrocracker, Hydrogen unit and Thermal cracker require extra energy for their processes.

Compared to Scenario 3 with just a basis configuration the refinery own consumption and losses were 1.5% on total crude run volume. In scenario 4 this rises to 2.6%.

It's the overall activity that requires more energy, although each unit is very efficient in its energy use.

Also the extra installed CHP gas turbines will need more gas input; Natural Gas or Propane and Butane from the refinery in order to deliver the required 30 MWh electricity and 400 ton day steam. These units are still 70-75% efficient compared with conventional steam generation of just 30%.

The sulphur recovery unit is a net energy supplier to the system, as it produces more heat than it consumes. Also the Hydrodesulphurisation is more than energy balanced as the process is exothermic; it releases more heat than consumed.

The thermal cracker is a net user of burner fuel and so is the Vacuum unit and Amine treater unit.

Overall the 2.6% consumption is low compared with older similar refineries.

2.4.8 Economics of Scenario 4

As it was done in previous scenario's, this scenario 4 setup will have its own profit and loss estimate for the refinery and the now minimal products purchase /trading part, and is based on calculated yields and Platts prices (see assumptions).

Operating Expenses

Due to the addition of units there will be more manpower needed and rises from 450 staff in Scenario 3 to 500.

Maintenance and spare part cost go up, but moderate as all new units will not require major routine maintenance or thorough overhaul for the next 10 years.

The purchase of Natural Gas increases for the larger capacity in CHP gas turbines to 30 MWh. However this gas purchase can be reduced but at the expense of own produced gases, propane and butanes. This should be calculated to see the CHP benefits of using refinery LPG instead of gas purchased in the CHP gas turbine process unit energy efficiencies and value.

The total expenditure amount rises, but this is due to the rise in the depreciation (4% per year) of the extra investments beside the Single Point Mooring at Kutubdia Anchoring and the investment in the CDU, CCR, Isom, CHP and all other units described in Scenario 4.

It is the depreciation of the process units and the SPM facility that is with 60% the main contribution to operating expenses.

		ERL		
throughput	crude tons	6,000,000		
	feedstock	0		
number of staff scen 3		500		
location type		sea/coastal		
supply/offtake		vessel/ SPM		
configuration		simple		
depreciation period major inv.	years	25		
	usd/mln	usd/bbl	%	
salaries/wages	5.0	0.11	8.1%	
other employee cost	2.5	0.06	4.1%	
chemicals	1.2	0.03	2.0%	
repair/maintenance	3.5	0.08	5.7%	
spare parts	2.0	0.05	3.3%	
fuel,power/water	0.0	0.00	0.0%	
gas purchase	9.4	0.21	15.3%	
insurance	1.0	0.02	1.6%	
crude oil handling*	7.0	0.16	11.4%	
shutdown	0.4	0.01	0.7%	
transport	0.1	0.00	0.1%	
depreciation**	28.0	0.63	45.6%	
other cost (catalyst)	1.4	0.03	2.3%	
electricity export				
Opex all	61.5	1.38	100.0%	
Opex excl deprec	$/bbl	0.75		
Opex incl deprec	$/ton			10.31
Visbreaker				0.00
new opex scen 2				**10.31**
*SPM, pipeline 25 y depr	175.0			
**Scen 4 invest; 25 y depr	700.0			

There is some undefined extra cost for all catalyst that is needed in each unit. Platformer catalyst is the most expensive, but al units will need make-up as losses take place during the operation. It is difficult to provide a estimate, but most units do not require regeneration and major replacement over 4-5 year periods.

The operating expense for Scenario 4 is then 10.31 $/ton or 1.38 $/barrel, which will be used in the overall refinery economics.

Refinery Margin calculation for Scenario 4

The methodology for refinery margin also in Scenario 4 is the difference between the revenue of all refined products, valued at the market parity price for Bangladesh Platts FOB Singapore, less the crude oil FOB load port purchase costs, less the freight on Suexmax class vessels and less the operating costs, **with depreciation on all new major investment included**.

Depreciation on all assets is 25 years.

REFINERY RESULTS	Scenario 4			USD/ton
		Refinery output		Platts Sing basis
		Kton	%	2007-2010
LPG		84.9	1.4%	657.44
Naphtha		199.8	3.3%	652.06
Premium		201.3	3.4%	720.26
Regular		300.0	5.0%	713.92
Spirits		136.9	2.3%	667.06
Kero		443.5	7.4%	735.46
Jet Fuel		383.6	6.4%	735.46
Diesel		2,954.9	49.2%	695.10
Jute/other oil		69.1	1.2%	685.10
Furnace oil		965.4	16.1%	438.00
Lubricants (import)		0.0	0.0%	920.00
Bitumen		103.9	1.7%	488.00
Refinery own used Fuel		156.8	2.6%	
TOTAL Product value		6,000.0	100.0%	636.61
Murban		960.0	16.0%	611.44
Arab Light		1800.0	30.0%	565.22
NGCondensate		240.0	4.0%	617.06
Forcados		2400.0	40.0%	585.68
Al Shaheen		600.0	10.0%	542.64
TOTAL Crude Oil costs		6,000.0	100.0%	580.62
Freight costs				18.56
Lightering				0.00
Refiners margin Gross				37.44
Refinery Operating expenses				10.31
Net refiners margin	**$/ton**			27.13
Net refiners margin	**$/bbl**			3.67
Total import cost crude	**mln USD**			**3595.0**
Total profit/loss on refining	**mln USD**			**162.8**

The result is positive at 3.67 $/bbl net margin or 163 million $ per year, because this Scenario 4 has major upgrading units; Hydrocracker and Thermal Cracker/Visbreaker, and with an Isomerisation unit.

There is considerable upgrading of low value Fuel Oil into high value Distillates, and low value Light Naphtha into Regular Gasoline blend component. These unit economics were discussed in detail under each unit description.

On the other hand there is a relative high investment amount required for the configuration, including the crude oil SPM facility to be constructed, and the high cost per barrel for unit depreciation (57% of total operating expenses) that has been taken into account.

However all product demand is produced now in Bangladesh and just small remaining imbalances in Diesel and Fuel Oil are imported. Important products as Jet Fuel, Gasoline's and all of the Diesel are meeting the regional strict product specifications and can be set as a starting point for improved environmental demands that Bangladesh should adopt..

Imbalancing/ Trading Results Scenario 4

As complement to the refinery product output and margin results there is still some but very minor imbalance trading activity required.

TRADING RESULTS	Scenario 4		USD/ton Purchase Cost AG Platts	USD/ton Revenue import parity
		Imports (- export)	Platts AG Arab Gulf	Platts Sing basis
		Kton	2007-2010	2007-2010
LPG		-34.9		657.44
Naphtha		-199.8		652.06
Premium		-76.3		720.26
Regular		-175.0		713.92
Spirits		-126.9		667.06
Kero		-143.5		735.46
Jet Fuel		-33.6		735.46
Diesel	import	545.1	681.90	695.10
Jute/other oil		-19.1		685.10
Furnace oil	import	404.6	422.48	438.00
Lubricants (import)		20.0	920.00	920.00
Bitumen		-3.9		488.00
		-156.8		
Average result before costs		0.0	13.90	0.00
Freight costs	**20-25000 ton**		22.50	16.40
Lightering			0.00	0.00
Trading margin Gross			-5.55	
Operating expenses	estimated		1.00	
Net trading margin		$/ton	**-6.55**	
Net trading margin		$/bbl	**-0.89**	
Total Balancing cost products		mln USD		**-11.7**

The trading part of this Scenario 4 shows a loss of just 11.7 million USD.

The main reason is the necessary transportation cost of all the exports to the Singapore markets. Throughout the analysis the for Bangladesh market parity has been Platts Singapore, and an export to Singapore will thus incur the transport cost as a loss. Also there is still the transport cost on the remaining Diesel and Fuel Oil imports.

Conclusion

Overall result for this Scenario 4	mln USD/year
profit on refining	162.8
A loss on importation and output balancing	-11.7
Total result for Scenario 4	151.1

Compared to Scenario 3 which had a similar loss on trading /imbalancing, and a 10.6 mln USD loss on refining, this Scenario 4 is financially entirely carried into well positive results by the quality of the investments leading to a good refiner's margin.

This is the first Scenario that is well sustainable for a long term operation without need for extra support. Instead the contribution as enterprise to the local economy must be a strong incentive to create further growth in the region. Expansion into Petrochemical facilities is an option to be considered at some time.

Scenario 4 is therefore better than all previous ones as control over Bangladesh oil product supply is now under own management and responsibility and generates a contribution to the local economy. Chittagong port is less congested despite the larger refining activity due to crude oil imports all supplied via the SPM pipeline facility and product imports reduced to only a small flow per daily averages.

This Scenario 4 refinery configuration is also among world comparable refineries, and has a Nelson characterisation Index factor of 7.6, well rated amongst sophisticated US and European refineries as in the table.

(The Nelson benchmark was discussed in the assessment report.)

Nelson Index table

	Scenario 4 for ERL, Bangladesh		Esso Baton Rouge, US gulf		BP Rotterdam, Netherlands	
	Rated Capacity in					
	000bbl/day	% CDU	000bbl/day	% CDU	000bbl/day	% CDU
Atmospheric Distillation	**100**	100,0%	503	100,0%	392	100,0%
Vacuum Distillation	**50**	50,0%	232	46,1%	86	21,9%
Thermal Cracking/Visbreaking	**10**	10,0%	0	0,0%	0	0,0%
Coking	**15**	15,0%	114	22,7%	59	15,1%
Catalytic Cracking	**0**	0,0%	229	45,5%	115	29,3%
Catalytic Reforming	**5**	5,0%	76	15,1%	30	7,7%
Catalytic Hydrocracking	**20**	20,0%	27	5,4%	0	0,0%
Catalytic Hydrorefining	**50**	50,0%	70	13,9%	0	0,0%
Catalytic Hydrotreating	**10**	10,0%	383	76,1%	348	88,8%
Alkylation/MTBE	**0**	0,0%	39	7,8%	9	2,3%
Aromatics / Isom	**5**	5,0%	10	2,0%	0	0,0%
Asphalt	**4**	4,0%	0	0,0%	0	0,0%
Lub	**0**	0,0%	16	3,2%	0	0,0%
Hydrogen	**5**	5,0%	22	4,4%	0	0,0%
NCI factor	**7,6**		**10,7**		**6,5**	

The Nelson Index reflects the significant investment in upgrading capability that took place in Scenario 4. It does not reflect any of the added energy efficiencies that this configuration also will have as its being build with the latest technologies on unit energy conservation.

2.4.9 Required Investments for Scenario 4

Scenario 4 is the combination of considerable but cost effective investment considerations but with this investment nevertheless directed towards a minimal imbalance and a high contribution to the refining profit. It also allows running a variety of heavy and light crudes (including all local produced Gas condensates) and is the most flexible whatever the crude oil base slate.

The volume of imported product is just now limited to some remaining imbalances and in light of the port logistic limitations there is the investment in a SPM /pipeline system which is assumed at approx 175 million USD. The cost of this SPM investment is not included here as we assume the commitment is already made and also the comparability with other scenarios would be distorted.

However the cost of the SPM depreciation is included in the refinery operating expenses.

In the Scenario 4 investment is therefore the refinery, and storage facilities.

All costs are estimates based on similar projects elsewhere and on the valuation methods described by the Petroleum Refining Handbook 2004 (fourth edition 2001: James Gary and Glenn Handwerk), revision/update in O&G journal 2007.

All estimates are indicative only and subject to change.

	mln USD
New 100.000 bbl/day CDU (incl. LPG Merox)	101.0
New 45000 bbl/day Vacuum Distillation Unit	65.4
New 5000 bbl/day Cont Regenerative reformer (CCR)	35.3
New 5000 bbl/day Isomerisation Unit	9.3
New 10.000 bbl/day Naphtha Hydrotreater	19.9
New 20.000 bbl day Hydrocracking Unit (Chevron Lummus)	161.9
New 50.000 bbl/day Hydrodesulphuriser	98.5
New 15.000 bbl/day Thermal Cracker	51.8
New Amine treatment Unit (60 ton s /day)	7.7
New Sulphur Recovery Unit (60 ton s /day)	18.4
New Hydrogen Unit (12 mmscft/day	17.8
Gas turbine CHP unit 3*10 +7 MW/h and 450 ton/d steam.	24.9
Crude oil storage 100.000 cbm	11.5
Distillate storage 45.000 cbm	5.0
Fuel Oil storage 30.000 cbm	3.6
LPG sphere plus pressure control valve/unloading rack	3.2
Water ARO expansion 400 t/d	2.0
API oil/ water separation	0.5
Flare expansion	0.2
ERL current unit refurbishments and modernisation	15.0
Investment for Scenario 4	652.9
Contingency 10%	65.3
Total estimated investment Scenario 4	**718.2**

The investments do not include any purchase of land, or the cost of demolishing old buildings at the current ERL site to make room for the new units and facilities.

Given the compact method of modern refining unit construction the necessity for extra land is not considered.

2.4.10 Scenario 4: Financial Result over a 10 year period

This Scenario 4 has the highest investment requirement so far.

It reflects the now sustainable modern to international standards refinery situation with a positive refiners margin, and an almost to zero reduced importation program and now just some imbalancing of finished product imports and exports.

Net present value/ IRR	**Scenario 4**										
interest rate	5.5%										
effective period	year	now	2	3	4	5	6	7	8	9	10
Investments	mln USD	-718.2									
refiners margin	mln USD	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
trading margin	mln USD	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
depreciation cash return	mln USD	35	35	35	35	35	35	35	35	35	35
total margin	mln USD	-532.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1
NPV	mln USD	$722.0									
IRR		32%									

The Net Present Value is a positive 722 mln USD over a 10 year period, and has an internal rate of return IRR of 32%. These impressive results all reflect the benefits of a serious investment and the synergy in the Bangladesh energy supply and demand.

The difference with all earlier scenarios is:

- Security of product supply.
- Building up of a physical and monetary sustainable oil infrastructure.
- A high standard quality product quality (sulphur and aromats) supply.
- Crude oil supply flexibility and therefore more supply reliability.
- Potential for further investment in a petrochemical industry.
- Capacity building in human resources meeting international standards.

2.4.11 Pro/strengths and contra/weaknesses of Scenario 4

The major difference between the current oil supply situation in Bangladesh and this Scenario 4 is the refined product portion of total demand now at 100% volumes with only some imbalances left and the reliability and quality of product supply.

Pro and Strengths

- Positive and long term sustainable refinery margin
- Relatively small purchase /trading imbalancing program.
- Overall inland product quality of regional standards.
- High unit efficiencies because of new unit construction technology.
- Very flexible mode of operation.
- Flexible crude oil base slate, including all local produced condensates.

- Existing storage facilities better utilised at higher refinery throughput.
- Implementation of international market price as basis for domestic prices.
- Introduction of CHP gas turbine technology with major saving on utility bill.
- Product sulphur and aromatics qualities improved with new CCR/Isom and Hydrocracking/Hydrodesulphurisation units.
- Almost complete sulphur removal meeting environmental air standards.
- Better long term reliability of country oil product supplies.
- Reduction of congestion in Chittagong port with introduction of SPM/pipeline crude upply.
- Potential for further expansion of a petrochemical industry, solvents, aromatics, ethylene cracking etc.

Contra and Weakness

- Investment 718 mln USD.
- Balancing product yield with demand yield leads to some but much less physical ovements.
- Other ports are not capable to import even the smallest product vessels.
- Daily supply efforts require a professional process engineering, scheduling and oil rading approach.
- Working capital requirements are high with crude oil payments to be paid within 30 days after Bill of Lading.
- Non payment is immediately penalised with loss of credibility.
- Investment may need to be financed from commercial loans and private company participation.
- Government need to lead a market product pricing policy with drastic change in current attitudes across all participants.

2.4.12 A possible alternative to the Kutubdia Anchoring Point SPM facility

The Crude Oil Supply Fall Back

This description is for the same new refinery at ERL as described here in scenario 4, with crude oil discharge from Mother Tanker at Kutubdia anchorage point through larger lightering tanker (of 50000 – 60000 MT carrying capacity) to a jetty (to be constructed) in Sandwip channel with a draught availability of 11-14 meters at the anchorage point.

This Fall-Back recommendation is deemed essential, in the event that should the SPM project at Kutubdia Anchorage point,an essential part of Scenario 4 (firm recommended option) stall or in the worst case, should remain immaterialized.

The proposed jetty site at Sandwip channel is about 1.75 Km deep inside sea from coastal embankment behind Chittagong Export processing zone (CEPZ) at Halishahar Chittagong. The draught at some points of approach channel from Kutubdia is about 8.5 meters. But during the high tide, water level normally increases by 3 meters.

Therefore, a safe draught of over 11 meters is available twice a day during high tide for tanker loaded with 50,000 MT cargo (without restriction on night navigation). The tanker can leave the jetty without load, even at low tide. A draught of 11 meters is quite sufficient and safe for navigation. No pilot vessel will be required for entry and exit of the tankers. Following table shows the tanker type, parcel size and required draught.

Tankers Type	Max. Parcel Size (000 MT)	Draught Required(Meter) Fully loaded
Suez Max	80-150	14.00-17.00
LR-II	60-80	12.00-13.00
LR-I	46-60	11.00

Therefore, said location is considered suitable and safe for transportation of crude parcel of 50,000 MT by engaging Suez Max/ LR-II/LR1 type tanker. This was studied and recommended in an earlier pre-feasibility study carried out by Indian Oil Corporation Limited (IOCL) and Hindustan Petroleum Company Limited (HPCL) in 2002. It may be mentioned that crude parcel of this size came to this area when the defunct OSOT (Offshore Oil Terminal) was built at the initial stage for ERL Refinery.

The proposed jetty at Sandwip channel will not interfere with existing jetties' operations, shipping and anchorage system.

Project Description

- Fixed Platform type Jetty, 1.75 Km out in the sea at Sandwip channel.
- Jetty size should be big enough to be capable of berthing tanker with load of 60,000 MT crude oil; capable to accommodate 4 loading arms, pipe line manifold , fire protection system, control room with communication system etc.
- 1 no. 30 inch diameter pipe line (2Km under seabed and rest 6 Km underground) up to refinery for crude oil reception.
- Provision for products import may be kept, but such requirement is not envisaged even in future. Scenario 4 estimates an import/export requirement of about 1.6 million MT/ year; this can be handled through the existing jetties (including DOJ-7, used for crude oil reception). Existing jetties (including DOJ-7) are well capable of handling further import/export quantum of 1million MT/year.
- Provision for supply of bunker fuel and fresh water.

Mode of Crude Oil Discharge and Technical Feasibility

- Crude oil import target is 6 million MT/Year i.e 500,000 MT/Month.
- Crude oil is proposed to be brought in parcel of 100,000 MT; Mother tanker anchoring at near Kutubdia around 80 Km from the jetty at Sandwip channel.
- Suez Max/LR-II type tanker will be engaged on time-charter basis to lighter the whole crude parcel.
- Requirement is the lightering vessel of such type carrying a load of 50,000 MT crude oil, should release the Mother tanker carrying 100,000MT of crude oil within 72 hrs. and unload the whole parcel of 100,000 MT within 5 days (5 trips of Mother tanker have to be accommodated per month).

First lightering trip starts from Mother tanker at Kutubdia point; loading time 10-12 hrs. @ 5000 MT/Hr pumping.

- Voyage time to reach jetty at a speed of 15 Km/hr is 8 hrs. including adjustment for high tide.
- Berthing at the jetty and discharging to ERL tanks through the pipe line @ 2500 MT/hr pumping- time needed 20hrs.
- Return trip to Mother tanker- 6 hrs (empty lightering vessel can travel at low tide).

- Takes the second load of 50,000 MT ; pumping time 10-12 hrs.; releases the Mother tanker.
- Total time required 58 hrs.(12+8+20+6+12) .

The loaded lightering vessel needs time for trip to jetty , discharge the load and return to Kutubdia point; further 34 hrs.(8+20+6) is required.

- Total time to unload the 100,000 MT parcel is 92 hrs., much less than 5 days.

Both requirements can be met in this system. As such it is technically feasible.

Investment Requirement and Economic Considerations

Pigging has not been considered, instead a sunk investment for dead volume of crude oil in the pipe line has been estimated. For a 30 inch dia 8 Km long pipe dead volume comes to around 3367 cubic meter equivalent to around 22,000 bbls. If there is no effective Pigging system in the SPM project, dead volume for that project will be at minimum 10 times of 22,000 bbls.

Same is true for pipe line and SPM cost. Therefore, it can reasonably be inferred that the cost of the jetty with pipe line for the Fall-Back system will not be more than 10- 15% of the SPM project cost.

From economics point of view, if financing cost of additional investment requirement for SPM project along with much higher depreciation cost , booster pumping cost and other associated operational expenses are considered, lightering cost for the Fall-Back system is more likely to be quite comparable and competitive.

However the construction cost of the Fall Back Jetty (estimated at 17 million USD) with a 3 km pipeline to the shore and on to the refinery will be increased by the costs of lighterage by 50.000 ton vessels. This cost is estimated at 4 USD/ton (0.54 USD/barrel) excl demurrages.

Total cost of this option then is estimated to be in excess of 0. 65 USD/barrel).

2.5 Scenario 5 Strategic Development of a new Refinery complex and location in Bangladesh

2.5.1 Brief Description

The previous scenarios dealt with the existing revitalised 33000 bbl/day ERL facilities in Chittagong with additions and modification in an increasing complexity of modernisation and BRME. In that review the refinery location remained at Chittagong in all scenarios to fully benefit from the existing infrastructure in storage, jetty, and other logistics and the refinery units. However this leaves the current refining location with the limitations of just one location, limitation on further expansion, Chittagong draft and all facilities for redistribution to depots.

The possible construction of a refinery and other energy/petrochemical facilities in a new location must take these disadvantages into account. With regard to the latter, the following aspects (not limited to) will be analyzed:

- Size of the refinery.
- Location (taking into account the geographical and port conditions and the location of the main market centers);
- Technical structure of the refinery (operational facilities, process units, offsite facilities); and optimal crude oil base slate.
- Downstream infrastructure required to transport and store the products;

- Stay open for expansion into Petrochemical areas if justified (Naphtha and Gas condensates as Steam cracking feedstock for polyethylene/propylene manufacture). Also possible addition of a LNG unloading facility.

An entirely new 100.000 barrel/day refinery complex, at deep draft waters will be reviewed in this scenario near Kutubia Island to benefit from a short stretch Single Point Mooring with at least 17 m draft and avoiding the long vulnerable pipeline connections to Chittagong.

The new refinery would benefit from the advantage of latest refinery technology, similar to Scenario 4 and general port infrastructures like the recently build grass roots refineries in Vietnam and Middle East.

The refinery will be the same as the one discussed in scenario 4. This means a new CDU, VDU, Continuous Catalytic Regenerative Platformer (CCR), an Isomerisation Penex unit, a Single stage recycle or two stages Hydrocracker, large Hydrodesulphurisation capability and a soaker drum equipped new Thermal Cracker. All other utilities meet electricity steam and power demands.

This project will evaluate the associated costs of a grassroots build refinery with cost guidance from Petro Vietnam's 2009 Dung Quat refinery and 2007 Sohar refinery in Qatar. The total costs will include the marketing logistics cost to inland terminals from a location like Kutubia preferably via a dedicated products pipeline from the refinery to Chittagong, Dhaka and further North.

The current ERL refinery remains as it is now but with modernisation and refurbishment as described in scenario 2 and 4, and will be the 'second' (bitumen specialised) refinery in Bangladesh.

Of course this last Scenario 5 will be the most expensive of all previous scenario's but is nevertheless an option and with the configuration setup incl. all latest available technology as described in Scenario 4 and a new port, storage facilities, pipelines etc facility.

The discussion in Scenario 5 will focus primarily on all aspects of the location, while the refinery configuration will be as it was described in the previous Scenario 4, with the same output, products quality and quantity, efficiencies and refiners/traders margin.

In fact the economics of Scenario 5 will be focussed on location and the investments associated with that and the refinery is then the one with full analysis and data from scenario 4.

2.5.2 Location

Considerations

The choice of location is vital to this Scenario as it will have an impact on cost and the way the future energy supply structure will be organised.

There are a few basic considerations that must be reviewed.

- The location site must be large (250 acres) and structurally sound enough to accommodate all process units, tank storage, and logistics facilities.
- The site must be convenient to be reached by vessel, truck, rail, etc means of transport.
- Available Draft is vital and should be considered as highest priority.
- Preferably not in densely populated regions.
- Preferably close to the main consumption area; Dhaka and surroundings.
- Direct discharge for crude and product imports and exports. No lightering.
- Sufficient potential civilisation nearby for staff housing etc.

The Location Choice

Without being repetitive, the main limitation for Bangladesh as a low land relatively marsh country is the **available draft** for supply of crude and and import-exports of products in an efficient time and cost manner.

Lightering of Suezmax size (130-175.000 ton) crude oil vessels with a supply obligation to a 100.000 barrel day refinery is not an option logistically and neither can the operation afford to pay the expense for lightering costs. Sufficient arguments have been discussed in the Assessment report and in Scenario's 3 and 4.

From many expert interviews, among these the Chittagong Port Authority, the fact is that none of Bangladesh harbours have such draft. The deepest on shore harbour is Chittagong with 9 meters (at high tide).

Therefore the crude oil supply process starts at the nearest to shore deeper draft (over 17 meters) anchoring points out at sea.

The nearest suitable location is 12 km from Kutubdia Island, and is the prime location for a SPM +pipeline transport system to shore, which as is understood is approved and being constructed. The cost was advised to be near 175 million USD, which includes a 75 km long 3500 cbm/hour pumping capacity pipeline connection to Chittagong ERL crude oil storage tanks. A new refinery location near Kutubdia will only require a short pipeline from the SPM to shore.

The location of the new refinery anywhere else than Chittagong will mean that all infrastructure facilities have to be build, not only the process units as described in Scenario 4, but also:

- all storage tanks for crude oil, and finished and intermediate refined products.
- facilities for clean water, waste water, flare system, smoke stacks, cooling towers, roads, electricity cables, transformers etc
- Jetties and new quay plus shore enforcement, with a direct shore draft of at least 9 meters to allow loading of inland river barges and small depot tankers.
- Jetties to accept sea going product vessels of at least 25.000 tons capacity.
- Rail, Road, pipeline connections to other depots.
- Pipelines connecting all process units, tanks, loading and discharge.
- All refinery office buildings, laboratory, loading racks, weighbridge, warehouses, maintenance facilities, lifting equipment etc.

It is beyond this study to give cost estimates for all civil work, the construction of new harbours and jetty access points, dredging out of port channels, construction of bridges, roads, bonding, and all other facilities that need to be build as if to create a second port like Chittagong.

These infrastructures are very expensive and time consuming and are always justified if other activities in that new port facility can be served in synergy. A new port creation and preparation of the location just for oil refining is an activity that needs careful study between all potential users, stakeholders, competent authority approvals, with preparation of cost and time estimates,. Usually these infrastructure projects have a timing horizon of 10 or more years and an investment of hundreds of million or even billions of dollars.

To make a judgement whether Scenario 5 is a viable and realistic situation there must be some cost/benefit analysis without accounting for the investment in port facility infrastructure.

The approach suggested is the listing of all savings of cost and expenditures and extra incurring of directly oil related costs that would be relevant in addition to the investments as discussed under Scenario 4. The base case is Scenario 4 with of course the location Chittagong.

Location 1 - Kutubdia Region

If a suitable minimum 250 acre shore location at or near Kutubdia or Matabari is available then the following remarks can be made;

Draft at the immediate shore, as inspected visibly is less than 3 meters and there must be an extended into the sea jetty complex or a dredged channel that will allow sufficient draft for loading of all depot destined barges and small tankers. Also the jetty structure will require facilities for bunkering and other supplies to these depot vessels like available in Chittagong.

Such a jetty complex will be of the same structure as the concreted build of Jetty 6 and 7 and likely need some dredging to secure sufficient draft at all times and may well be a continuous activity to prevent new silt deposits.

Loadings and discharge of seagoing 25.000 ton product tankers require at least 9 meters draft and are best served at the main SPM facility. This means extra product pipelines (for clean and dark products) from the refinery location to the SPM. It also will require at least a second mooring point as the crude discharge SPM is a continuous activity and occupancy is almost permanent.

There will be extra shipping costs for depot supply as vessels will have to cover an extra 70+ km distance compared to current Chittagong as MI load point.

The Refinery will need a full set of storage tanks, at least the same capacity as the current ERL and MI storage capacity. This is then a new build storage facility at the refinery site and equal to the 572.000 ERL and 325.000 Main Installation cbm capacity.

The site must be of sufficient strength and higth to withstand the forces of nature and the shallowness of the land to secure the refinery site sustainability

The new port must be open 24 hours to prevent daytime only congestion, as is the case in Chittagong.

The location also has cost saving advantages:

The SPM required pipeline connection is limited to perhaps 15 km instead of the 75 km Chittagong connection between the anchoring point and the refinery crude oil terminal.

Land is most likely cheaper in the Kutubdia region.

A very indicative and of course global indication of the main extra (oil related only, so exclusive for jetties, mooring facilities, dredging, anchoring etc) costs over Scenario 4 can be summarised as:

Scenario 5 extra oil related costs for the Kutubdia Location:

- A new full set of storage tanks to approx 900.000 cbm will cost by rough approximation 108 million USD using a rule of thumb approach of 120 USD per cbm capacity.
- All pipelines, valves and pumps from process units to storage tanks and jetty, by approximation 1 million USD per km. Assessment at well over 30 million USD.
- Extra 13-15 million USD/year shipping cost for the extra distance Kutubdia to Chittagong at an estimated extra bunkering, and other shipping cost of 3 USD/ton over almost all (100.000 barrel/day) refinery output of 4.5 million ton/year. This is 0.45 USD per barrel extra marketing operating expenses. The refiners margin as in scenario 4 of 162.8 mln $/year will be deducted for extra shipping costs of 15 mln $ and becomes 147.8 mln $ for this location scenario.
- Extra SPM mooring facilities and extra 12 km double pipelines (clean and dark) for import/export of sea going product vessels. Estimated 35 million USD. (the 2 pipelines at 25 million USD extra). Alternative is to use Chittagong MI and ERL installations to import and export the oil products and will avoid the cost of extra product pipelines, but will add to the Chittagong port activity.

- The necessary reinstatement of the lightering operation to the in this scenario 5 still active ERL refinery. With the SPM crude supply redirected to nearby shore there is no pipeline supply to ERL. This lightering cost was assessed at 5 USD/ton or 0.65 USD/barrel extra addition to the operating expenses.

Kutubdia Location Cost Saving in this Scenario 5

The 75 km pipeline from the crude oil SPM is now only 15 km. With an estimated advised cost of a sea bottom anchored SPM plus pipeline of 175 million USD for Kutubdia to Chittagong. The saving for only 15 km pipeline length compared to the original 75 km may be as large as 100 million USD less investment cost. This depends also on the current choice for the pipeline, land based or sea bottom based as sea bottom anchoring is much more expensive due to the construction requirements, but also more vulnerable to currents and other damages.

Summary of cost findings for the Kutubdia location

For the Kutubdia location with all these, very arbitrarily, estimated cost numbers the total may be an extra oil related cost over Scenario 4 of 173 million USD less the potential 100 million USD saving on current SPM investment.

Net extra oil related costs for this location is then 73 million USD and extra operating expenses of approx 1.00 USD per barrel crude to ERL due to the lightering costs into Chittagong and the extra sailing distance cost from the Kutubdia location compared with Chittagong.

Of course as pointed out, these costs do not include any of the port infrastructure civil engineering required investments.

Location 2 - Dhaka Region

The previous location had the advantage of lower SPM investment, near to the refinery crude oil supply and flexibility to the infrastructure. Its major disadvantage is the location which is far away from the major oil product consumption area which is in the Dhaka region and also the cost effective supply to other depots from a more central near Dhaka location refinery.

This location choice is only feasible and realistic if there is:

- A proper solution to transport the crude oil from deep draft (over 17 m) water near the Kutubdia area all the way to a Scenario 4 refinery near Dhaka.
- A suitable and long term secure 250 acre building plot near the river and existing oil terminals.

All other considerations are as in the previous discussion. The following remarks can be made for this location.

Draft at the Meghna/Padma river must be sufficient to handle all inland depot barge movements. Dhaka refinery storage facilities will now act as central distribution point for further inland depot supply and this may require some modification or new build jetties and possibly new jetty facilities.

Also a dredged channel that will allow sufficient draft for loading of all depot destined barges and small tankers.

Loadings and discharge of seagoing 25.000 ton product tankers (the imbalances as discussed in scenario 4) will need to be handled at Chittagong and products if will come from the ERL refineries production, or alternatively be shipped from Dhaka to Chittagong for reloading on to 25000 ton product vessels.

The crude oil supply will come from the Kutubdia SPM with a pipeline that will be the crude oil transport connection over 270 km and will be land and possibly seabed based. These lengths are quite common in Europe, USA and Russia. The Druzhba pipeline is the world's longest oil pipeline in fact one of the biggest oil pipeline networks in the world. It carries crude oil some 4,000 km (2,500 mi) from the eastern part of the European Russia to points in Ukraine, Belarus, Poland, Hungary, Slovakia, Czech Republic, and Germany. The Druzhba pipeline currently has a capacity of 1.2 to 1.4 million barrels per day. The diameter of the pipeline varies from 420 millimeters (17 in) to 1,020 millimeters (40 in). It uses 20 pumping stations and is mainly build over land.

The new refinery will also need a full set of storage tanks, at least the same capacity as the ERL and MI storage capacity.

The site must be of sufficient strength and height and likely need underpinning of the process units.

There are large costs savings in a Dhaka located refinery, with all savings to come from the depot structure transportation saving with a centrally country wise located product supply source.

However the cost will be the general infrastructure costs as discussed under Location 1, and the pipeline investment from the SPM to Dhaka. This is a realistic opportunity with many pipelines being much larger and longer and must be a consideration for Bangladesh. In depth technical pipeline studies should be done if this location is supported. Most likely the pipeline would be over land to reduce cost and will require booster pumping stations to maintain the required 3000-3500 cbm /hour pumping capacity.

A very indicative and of course global indication of the main extra (oil related only, so exclusive for river jetties, mooring facilities, dredging, anchoring etc) costs over Scenario 4 can be summarised for the Dhaka location as:

Scenario 5 extra oil related costs for the Dhaka Location

- Like in the other location there will be new storage tanks to approx 900.000 cbm, which will cost by rough approximation 108 million USD (using a rule of thumb approach of 120 USD per cbm capacity.)
- All new pipelines, valves and pumps from process units to storage tanks and river jetty. Assessment 30 million USD.
- The current SPM plus crude pipeline project from Kutubdia to Chittagong is advised at an investment of 175 million USD. The extension to Dhaka is another distance of 200 km, and assuming a (20 inch) pipeline construction cost over land of estimated 1 million USD per km implies an extra 200 million USD investment.
- The cost of a branch from the crude oil pipeline into ERL Chittagong for supply to the existing ERL refinery. Since the direction is north there is just the cost of a manifold without an increase of pipeline length. Estimate at 1 million USD for a tie in to the line.

Dhaka Location Cost Saving in this Scenario 5

The products that are consumed in the Dhaka region are currently 33.6 % of demand and just 22 % is consumed in the Chittagong region. The remaining 44% is redistributed among the depots. Although the assumed 6 million ton/year demand is likely not identical in distribution, it is assumed that this is the case for this purpose here, and in addition there is the nearby airport for the increasing Jet Fuel supplies.

Table and Figure 2.5 - BPC Regional Sales, per Division (FY2009)

Divisions	Consumption (tons)	Share (%)
Dhaka	1,117,552	33.6%
Chittagong	729,857	21.9%
Khulna	583,859	17.6%
Rajshahi	575,660	17.3%
Barisal	178,586	5.4%
Sylhet	141,235	4.2%
TOTAL	**3,326,749**	**100.0%**

Source: BPC

This means that there is a saving of at least 65 % volumes that do not require barge transportation for the distance Chittagong to Dhaka since the main 100.000 barrel day refinery is in Dhaka and the now second refinery; ERL is sufficient to meet the 22% demand in the Chittagong region and continues to supply some of the barges into the coastal areas at Mongla, Barisal.

BPC and the marketing companies assessed the transport cost Chittagong to Dhaka at 0.27 taka per litre; this is equivalent at 5.00 USD/ton. This is an expensive tariff and will support the extra cost calculation in this Scenario 5 location Dhaka by saving 65% of 6 million ton/year at 5 USD/ton which is 19.5 million USD/year.

Summary of cost findings for the Dhaka Location

For the Dhaka location with all these estimated cost numbers, the total may be an extra oil related cost over Scenario 4 of 339 million USD. Savings are at least 19.5 million USD per year on the barge transport from Chittagong.

Over a period of 15 years these barge transport cost savings and the additional extra 339 million USD investment come to a Net Present Value (at 5.5% interest rate) of negative - 135 million USD, which is the extra cost for this location.

Other Locations

Since the SPM anchoring point is vital for supply of refinery crude oil supply and the main products consumption is in the Dhaka region the 2 most optimal locations for Scenario 5 have been discussed. Any other location will either increase the total cost of transportation both for the SPM pipeline and the cost by barge, road or rail.

Draft at the next best location, the Mongla region, is just 6 meters and not suitable to accept any sea going vessel and in addition is the redistribution from Mongla to other deports throughout Bangladesh not very well located.

Furthermore the Kutubdia region location has the advantage of the potential for other import of energy such as Liquid Natural Gas (LNG) and LPG as discussed elsewhere and has sufficient room to enlarge the refinery with a Petrochemical industry. Neither Dhaka location or Mongla would be in a position to support these.

Evaluation of the Scenario 5 locations other than Chittagong support then the refinery construction in the Kutubdia region with 73 million USD extra cost to the in Chittagong based Scenario 4 refinery compared with the Dhaka location with 135 million extra cost.

These are ONLY the extra oil related costs and there is no provision for the usually very high costs of the port infrastructure that needs to be made prior to any construction of the refinery.

2.5.3 Scenario 5: Financial Result over a 10 year period

This Scenario 5 is the addition of the extra 73 million USD **oil related cost** for the Kutubdia region added with the Scenario 4 refinery investment of 718.2 million USD

The total of the 73 million USD is much less exact that the refinery investment estimates and can be considerable different, depending on actual pipeline- and SPM costs etc.

Nevertheless the total oil related cost will be higher than in scenario 4 because of a complete new location for the 100000 barrel day refinery construction.

Net present value/ IRR			**Scenario 5**		100.000 bbl refinery in Kutubdia region plus ERL Chittagong						
interest rate		5.5%									
effective period	year	now	2	3	4	5	6	7	8	9	10
Location oil related cost		-73.0									
refinery Investments	mln USD	-718.2									
refiners margin	mln USD	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
trading margin	mln USD	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
depreciation cash return	mln USD	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
total margin	mln USD	-605.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1	186.1
NPV	mln USD	$652.8									
IRR		27%									

The Net Present Value is a positive 653 mln USD over a 10 year period, and has an internal rate of return IRR of 27%. These results are below the Scenario 4 results as there is the extra oil related cost with the Kutubdia location for the new refinery.

2.5.4 Pro/strengths and contra/weaknesses of Scenario 5

The major difference between the Scenario 4 and this Scenario 5 is in the location of the new refinery configuration. There are advantages but also weaknesses compared with Scenario 4. All pro and contra arguments of the refinery will also be valid here so only the location related pro and contra are listed:

Pro and Strengths:

- Existing storage facilities at ERL are more than sufficient to handle any exports and imports.
- Further reduction of congestion in Chittagong port with introduction of SPM/ pipeline crude supply from Kutubdia anchoring point.
- Potential for further expansion of a petrochemical industry, solvents, aromatics, ethylene cracking, LNG and LPG import facility etc.
- Cheaper land purchase prices.
- All advantages of latest technology refinery and logistics/storage features

Contra and Weakness

- Extra oil related investment 173 mln USD, less the savings of 100 mln on the SPM infrastructure investment.
- Other ports are not capable to import even the smallest product vessels.
- Kutubdia is the physically furthest away from main consumption region Dhaka and thus increases dependency on barge, truck, rail transportation.
- Staff needs housing and town infrastructure.
- Port infrastructure cost will be enormous, not taken into account here.
- Time horizon well over 10 years to develop.

- Port infrastructure expense now only depending on oil industry.
- Draft at immediate waterfront still too shallow to move depot serving barges freely.
- Area is more prone to cyclones and has risks to the overall operation.
- Less (not quantified) synergy as refinery operations split over 2 locations.
- ERL Chittagong refinery again needs the cumbersome lightering for its crude supplies.
- No advantage from existing oil infrastructure.

3. Summary, Comparison and Recommendation of the 5 Scenario's

The past chapter 2 discussed in details the variety of possibilities for the refinery setup for Bangladesh. It was all based on the basic concepts of available technologies, product valuation as per international market prices (Singapore region) and the assumptions specific to this study.

Discussed were the investment values to indicate the unit costs as investment. These are not exact values as for each realised project the final design parameters are different and also cost of materials, labour, complexity of design, location etc do vary significant.

3.1 Comparison with other Refineries

A project like the new build Dung Quat Refinery in Vietnam costed over 2 billion USD for a deep conversion 130.000 bbl/day refinery, but included also the construction of port facilities and harbour infrastructure beside the refinery and logistics facilities. The refinery runs local produced Bach Ho crude oil plus a variety of mainly Indonesian crude oils.

3.1.1 Dung Quat (Vietnam)

Key Data:	
Order Year:	1997
Annual Output::	Propylene 108,000t; LPG 286,000t; unleaded petrol 1.9 million tonnes; kerosene / jet fuel 282,000t; diesel 3.4 million tonnes; fuel oil 115,000t
Location:	Dung Quat, Vietnam
Estimated Investment:	$3bn Originally Petro Vietnam estimated the project to cost $1.3bn, but the engineering, procurement and construction (EPC), including the port infrastructure costs went up to $2.5bn, and finally the project totaled $3bn. The input materials, testing, land clearance fees, port facilities and management costs raised the project cost by $500m.
Construction Start:	November 2005
Completed:	February 2009
Key Players:	Sponsors: Petro Vietnam, Vietnamese Government
Contractors:	Technip-Coflexip, JGC Corp, Technicas Reunidas, TPC Complex, Technip, Technip Geoproduction and Technicas Reunidas, SmartPlant, Vinalines, Gemadept, Abnormal Loading Engineering and Stone and Webster
Financing:	PetroVietnam Crude oil sales, Bank for Foreign Trade of Vietnam (Vietcombank), BNP

3.1.2 Sohar Refinery, OMAN

Key Data:	
Order Year:	2000
Construction Started:	2004
Project Type:	Refinery expansion; Atmospheric distillation crude unit with capacity of 116,000 bpd and a Residue Fluidised Catalytic Cracking (RFCC) unit with a capacity of 75,260 bpd.
Location:	Sohar, Oman
Estimated Investment:	$1.3bn
Completion:	April 2006 (problems have kept the refinery off its full capacity)
Sponsors:	The Sohar Refinery Company - Oman Oil Company, Government of Oman, Shell.
Contractors:	The EPC (Engineering Procurement and Construction) contract for the project was awarded to a Japanese consortium (JGC Corporation and Chiyoda) in July 2003 for a lump sum of $880m).
Financing:	Japanese Bank for International Cooperation (direct loan of $261.9m), Nippon Exports Insurance Company ($261.9m), Bank of Tokyo Mitsubishi and a further ten banks ($907.8m). Bank of America Securities has been appointed as the financial advisor to the project and the Omani Government stake in the project is overseen by the Oman Ministry of Finance.
Valuation justifications:	The valuations in this study are reflecting in the best possible manner the cost of units as in other locations recently realised beside a mathematical cost history methodology as described in the refinery technology handbook from J Gary and S Handwerk, plus recent adjustment of that method published in the Oil and Gas Journal of 2007. Also product and crude prices (Platts Oilgram based) do vary from day to day, as well as other valuations of Gas and electricity/water etc. However since all values are consistently used in each Scenario there is a very good basis to compare the results in a proper and reliable way.

3.2 Refinery Policy and Regulations Issues

Before comparisons and recommendations can be made there is the need to discuss the policy and regulations framework which will be of importance to the choice of refinery configuration and trading strategy underlying the sustainability of the project.

The key policy issues are:

- Future Pricing of petroleum products and gas; impact of subsidies/taxes other deviations from free market pricing policy.
- The application of taxes and subsidies on refined products and gas.
- Private company initiatives to participate unhindered in all petroleum products supplies and incl. investments in refinery and marketing facilities.
- Mandatory min/max petroleum product specification limits for regional and environmental reasons meeting present situation.
- Future private imports of alternative petroleum products to balance product demand (including LPG, LNG)

Policy issues will be discussed in more detail in a separate report.

Key Refinery Policy Issues

The inland or domestic price for refined product should reflect the international market prices.

Bangladesh uses a complex system to establish a price setting mainly to establish the apparent need for subsidies.

Part of the recommended methodology is the assessment of market parity prices (as we recommend on basis of international acceptable price reports such as Platts and Argus). Throughout this study prices have been based on Platts Singapore FOB for all products, with a motivation discussed in the assessment.

Also this applies to other energy sources like Natural Gas, CNG and LPG. These also should reflect true market price levels and be competitive just because of their ability to contribute at the right price.

Most countries use a parity basis similar to their regional but reflecting international oil product market price levels, with the exception of a few (oil producing) countries that share their wealth with the domestic market, but still use Platts prices for their sales to off takers.

Taxes are applied in almost all countries for a variety of reasons.

Primary objective is to reduce excess demand by increasing the oil/product price. This also has the beneficial effect that energy is used in a efficient manner. In general most use a levy and or duty on the refined product price, which is a direct source of revenue to the State Treasury.

Alternatively, taxes can be raised on all imports of crude and products, but in a society where most products are inland produced the most secure way is a tax imposed on products at the refinery gate, and where the oil refiner is made responsible for collection and accountability to the raised and to the Treasury transferred taxes.

Taxes will also provide State revenue for example to finance major projects in the Petrochemical industry and other associated infrastructure. This is important to Bangladesh as the investment in a petroleum refinery is significant and bank loans may need accelerated refinancing if the sector credibility is unknown or weak. Beside a refiner's margin, which may be fluctuating, the security of revenue will be a major tool to secure financing for the project.

For Bangladesh with 6 million ton/year petroleum product consumption even a small tax of 10 Taka per litre levied on each product already provides 1000 million USD per year revenue to the Treasury, and a 10 Taka taxation of just the transportation fuel use already provides 510 million USD / year.

Petroleum Tax Revenue per year

taka/liter	all products (mln usd/y)	only transport fuels =50.7% (mln usd/y)
1	100,8	51,1
2	201,7	102,3
5	504,2	255,6
8	806,7	409,0
10	1008,4	511,3
15	1512,6	766,9
20	2016,8	1022,5
25	2521,0	1278,2
30	3025,2	1533,8
35	3529,4	1789,4

The taxation as a source of revenue is therefore significant even if only transportation fuel use is considered (and agriculture, industry, power generation use is excluded.

Subsidies are in most countries only limited to target group use, such as agriculture, priority development projects and public transport.

In Bangladesh, where all products are receiving a subsidy (often a price setting well below the market parity price) under the current system is unheard of to our knowledge.

Subsidy in the wrong places only encourages increased demand and inefficient use.

Better to allocate a lower tax rate to the dedicated user classes. For example the Agricultural use of diesel in harvesting irrigation etc machines is in many countries not taxed, or at a low tariff. Usually a red dye is added to identify the correct use and simplify the customs verification on the sector use of that oil product.

Selective and sparse use of subsidies also prevent fraud, adulteration and other non legitimate action, while it benefits only the groups that will directly need such a subsidy. It is not this study objective to recommend or make decisions on who needs to be subsidised, as long as it is used with care and within an overall policy structure.

The Private sector has not been involved in the production and distribution of (main) oil products.

This exclusion of full participation on economic competitive basis (with the exception of small volumes of LPG, Lubricant and Bitumen, and some fuel oil) is not stimulation new investment and lower consumer pricing pressures. All responsibilities are assumed by the State and allocated to BPC for execution.

Central coordination has advantages with regard to knowledge and national security control, but the private sector is also a source of capital for investment in the refining and logistics as discussed in the scenarios. Also private involvement will increase efficiency and competition in a free market and therefore will be guarantee for the lowest price to the consumer.

Of course there are many varieties for involvement but in this context the private sector may well provide the capital and the investment required or use their international credit rating more successfully in the international banking community than governmental borrowing can achieve.

Also private companies have to be efficient in managing costs and revenues, usually better than state oil type of companies where competition is not seen as a force to improve the operational efficiency. Aspects also cover the availability of knowledge to cope with technical and commercial matters underlying the oil industry. This covers entrepreneurial initiative, but also a more general higher educational level within the company than within governmental departments.

Therefore the private sector will under the right conditions provide capital, competition, knowledge and flexibilities for the oil product supply. To our knowledge there are no countries where private sector involvement is as strictly prohibited as in Bangladesh, except for some of the old communist structured economies.

Product specifications.

This will be discussed in detail in the separate report, but product quality will contribute to the wellbeing of consumers and will benefit ultimately in lower health costs.

Importation of crude oil and oil products should be without restriction.

As discussed under 4, the private sector involvement will be beneficial to the consumer to secure the lowest price because of competition.

But the volumes of product import as discussed in scenario's 1 and 2 are that high that other alternative may become interesting for the national energy supply. This will also require investment and manpower to realise these projects. LPG and even more LNG importation will be of importance to a energy poor country. The choice of scenario will therefore have an immediate consequence for alternative energy carriers; Nuclear, LNG, LPG, Shale, wind, tidal, Sun, and will in their turn require substantial amounts of money.

Summary Refinery Policy And Regulation

- Oil product and gas prices need to reflect true international market price levels to provide a sustainable demand and supply provision.
- Taxes are a deterrent for inefficiencies in energy use, and also income to the State for project financing.
- Subsidies need to be targeted to specific user categories and be identified critically.
- Private sector involvement in the oil supply will stimulate competition and lower prices, and will also be capable to provide capital for the oil industry infrastructure.
- Product qualities need to reflect regional standards and provide long term welfare.
- Imports activity of energy need to be accessible for all interested parties to participate both for direct supply to consumers and for the energy infrastructure.

3.3 Scenario Highlights and Summary

All data and scenario descriptions, calculations and performances are summarised in the table below for a comprehensive comparison.

Many of the issues discussed can be found again in detail in the main chapter where the scenarios were discussed. This summary is just for a reference and memory support.

Summary in words

Scenario 1: The base case. It is the current ERL refinery without any changes or modifications. All imports are purchased to meet a total domestic demand of 6.0 million ton/year. As a result shipping activity will be 4 fold of today's situation and Chittagong port will be congested even with a 24 hour operation.

The refinery is at a slightly negative margin, and the product purchases are all done in the AG region and transported on 20-25.000 ton tankers to Chittagong. This is the trading activity and is a major loss. All crude oil is lightered. Chittagong port will be over congested leading to a non realistic scenario.

Scenario 2: This is the current ERL refinery with some upgrade and increase in capacity and some modernisation of the main units, with the aim to change the overall refinery margin into a positive result. There is still a major import program with losses and port activity is unlikely to cope with this level of product importation. All crude is lightered. Product quality is well below regional standards

Scenario 3: Major increase in refining capacity to 100.000 barrel day or 4.5 mln ton year in Chittagong. Most products are locally produced and stored in the available ERL and MI storage facilities. Refiner's margin is negative as a simple addition of a large crude distillation unit with reforming/isomerisation is not sufficient to maintain positive margins.

All Crude supplies are pumped from the SPM facility and Chittagong port activity is normal. Investments of 230 million USD are moderate and entirely focused on meeting demand by local refined product. Different Crude oil types are a important tool to improve the refiner's margin. Product quality improves due to low sulphur crudes in the base slate.

Scenario 4: This is both a larger refinery to meet all demand and with 720 million USD investment in conversion technology to return to long term positive margins and to meet the strongly driven distillate local demand. There is no net importation but merely trading of minor imbalances between production and demand yield. Investments are significant although not exceptional high and guarantee long term sustainability. All facilities are in Chittagong on an enlarged ERL refinery plot. Crude oil choice is driven by margin contribution only.

This is the most sophisticated configuration and compares with nearby regional refineries.

Scenario 5: This is the new location for a 100.000 barrel entirely new refinery, and the 33000 barrel/day old ERL facility. Both together it is a configuration as described in Scenario 4. In comparison, the Kutubdia region is the most favourable, with Dhaka region and the choice is driven by oil related extra costs. The new port creation and infrastructure of harbours, storage tanks, jetties, pipelines etc are all disregarded to make the scenario comparable. However the construction cost of a new port will be enormous and can only be justified if other industries are using the same infrastructure. Extra cost will have to be made to transport oil to the inland depots from the remote but deep draft location and compensated for a saving/reduction in required SPM investment .

Scenario description		1 base case	2 minor mods	3 new 100 cdu	4 complex 133	5 new location
Location		Chittagong	Chittagong	Chittagong	Chittagong	Near Kutubdia
Refined products	mln ton	1,3	1,6	4,5	6,0	6,0
Net product imports	mln ton	4,7	4,4	1,5	0,0	0,0
Imbalances	%	1,3%	1,3%	8,8%	16,2%	16,2%
Total prod import bill	**mln $**	**3086,2**	**2868,7**	**1112,5**	**0**	**0**
Refiners margin	mln $	-6,1	12,7	-10,6	162,8	147,8
Trading margin	mln $	-39,9	-37,5	-12	-11,7	-11,7
Total margin	**mln $**	**-46,0**	**-24,8**	**-22,6**	**151,1**	**136,1**
Investment requested	mln $	2,6	15,6	230,3	718,2	791,2
Net present value	mln $	-349,2	-201,7	-268,0	722,0	652,8
IRR	%	na	na	na	32%	27%
Repayment amount 10 year annuity loan	mln $	$0,3	$2,1	$30,6	$95,3	$105,0
Spm		no	no	yes	yes	yes
Lightering crude oil		yes	yes	no	no	no
Port traffic		unrealistic	unrealistic	normal	light	new port
Prod quality		poor	improved	improved	meet region	meet region
Sustainable operation		no	almost	almost	yes	yes
Nelson index		2,3	2,5	2,4	7,6	7,6

3.4 Recommendations

3.4.1 What criteria to be used

Overall profitability and long term sustainability

It is important for the long term ability to survive without any dependency on loans or other funds. In market economies it is the main consideration for any private enterprise. Also financial support would cost interest which is an additional unwanted cost. All refined products shall reflect international market price as basis for domestic price setting.

Product import independence

This must be an important strategic consideration for a country with so much future growth potential. The ability to avoid expensive (refined product FOB cost and small vessel with high freight) imports and generate local refined product must be in itself a contribution to bottom line economics with refinery crude oil supply flexibility (including local Nat Gas condensates)

The ability to change crude oil type feed is important to remain flexible to both the positive margin contribution as well as independency from only few crude oil sellers. Furthermore the ability to efficiently process all the local produced condensates is for a energy poor country of great value.

Investment financing, funding and taxation

Financing of major investments will only succeed if governments have this ability to fund or otherwise have to rely on the investors who need to perceive a market rate of return on their investment as well as sufficient security that loans will be repaid. Private sector funding and banks will only consider a loan if these basic rules for private enterprise are met. Product consumption taxation must be one of the funding instruments.

Product quality

Any country will have the obligation to protect its inhabitants from health hazards. Competent bodies will adopt some quality limits in particular for sulphur, nitrogen, aromatics and other unwanted components in refined product use and the emissions to air, ground and water.

Maximum use of existing infrastructures

Chittagong has the basic petroleum product facilities that otherwise would all have to be rebuilt and otherwise funded if an entirely different location is considered. There is an enormous advantage to benefit from an existing infrastructure.

Freedom for 3rd party entry

Participation of private companies in the energy sector, construction of infrastructure, working capital funding etc, will satisfy the basic rules for competition, reduce the funding burden, and increase efficiencies and growth potential because of private entrepreneurial initiatives.

3.4.2 This Study recommendations

It is by now obvious that the Scenario 4, the full modernisation and capacity increase is **the prime recommendation** with provision of the required investment by government funding, and or from taxation, or via commercial loans from banks and other investors.

It assumes the existence of the crude oil SPM facility at or near Kutubdia anchoring point that will free any unwanted congestion in Chittagong and will allow maximum efficiency for the supply of crude oil.

This scenario must be the best solution for the country as it satisfies all above criteria with a moderate 718 million USD capital requirement for the new refinery (and existing SPM crude oil infrastructure). Timing from decision to start a FEED (front end engineering and design) study to completion of the refinery could be as fast as 3 years total.

For now a discussion who will lead the investment in scenario 4 refinery configuration is open. Private or Government parties may execute either exclusive or as joint venture or any other setup. However the advantages of a private sector participation as discussed should not be excluded.

The second recommendation should be the Scenario 5, an entirely new refinery at a different location, with all flexibilities to expand further for future projects in the petrochemical sector.

This option should only be considered if it is joined by the interests of other industries, trade, public and private infrastructure requirements. The costs of building and dredging out a new harbour will be enormous and is neither justifiable, nor sustainable for just the petroleum refining industry alone. It also is a long term project, and without any exact cost indication for the civil engineering of a second deep draft port creation in Bangladesh.

The third recommendation should be scenario 3, the expansion with just a basic distillation unit and a new Platformer/Isomerisation. Although this plan does not meet the refinery margin security and sustainability, it will make the country almost independent of product importation (apart from the imbalances) and thus reduce the trading costs of importation. Losses are very moderate and can turn to positive with further drives to efficiencies and items as crude oil type optimisation. Product quality is another issue as this scenario already has reduced unwanted sulphur in important products as Fuel oil, Gasoline's and Diesel.

Investment required is just 230 million USD, (and assumes there is the existing SPM crude oil infrastructure into Chittagong) but will likely have to be funded from internal resources (best to consider raising petroleum revenue for investment from taxes) as investors will not provide the funds without a positive economics fundament in this setup.

Additions to this configuration to improve the refinery margin can and should then take place at a later stage and will become the scenario 4 configuration with all associated benefits.

Scenario 2 is not recommended.

It does not satisfy the desire for own produced refined product supply to meet the local demand. Although there is some increased production with a positive refiner's margin that will provide the refinery with better long term sustainability there is no future for such a small operation, with the imports causing a large loss.

Then there is the expected over congestion in Chittagong port and it is likely to be unrealistic to expect all product flows; imports and redistribution to depots to be manageable through the port even at a 24 h day operation.

The required investment to upgrade the refinery is just 16 million USD, a very small investment which will turn the existing ERL refinery into a more profitable operation but otherwise will not contribute to meeting the demanded volumes.

In the unlikely situation that none of the above recommendations is supported by action, then there is the current base case situation where a very small refinery with no margin sustainability and increasing importation in a already today congested harbour will create a undesirable and impossible situation for the country future petroleum demand.

A good energy supply is required to provide economic growth which in the end must be one of the key pillars for the country future welfare. No decision will lead to low growth only, with rising costs for energy as inefficiencies are not removed in the no- decision scenario.

It is important to emphasize the need to avoid indecision.

Some of the inevitable consequences of no fundamental action in the Bangladesh petroleum industry will be:

- Importation is far more expensive than local own refinery production leaving the country with an ever growing cost for energy.
- The dependency on other (foreign) refining companies leads to upward product price pressure that cannot be held off without having an own refining capability.
- A proper refinery infrastructure is part of a growth creation. Petrochemical industries are securing long term employment. No action will miss out on this opportunity and consequently remain underdeveloped in the petrochemical sector and miss out on economic growth opportunities.
- No improvement in the quality of air, water and ground.
- No efficiencies in a rationality process for petroleum product demand. No state revenue or income from the industry via taxation.

4. Organisational and financial aspects

Over the course of the recommendation study the organisation that carries the oil refining, trading, administration etc has to be a reflection of the oil market specific to the Bangladesh region and the chosen scenario.

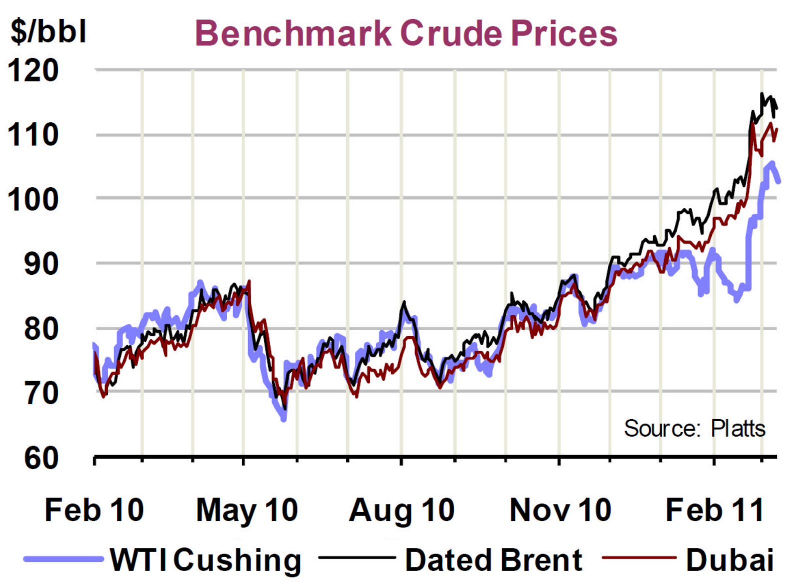
4.1 The Commercial Organisation

4.1.1 Oil Trading Department

Oil markets are unique and set demands on the structure of the organisation. Understanding the often volatile and unpredictable trends of global oil prices is vital to success in the international energy business. The organization has to provide the insight and analysis to make sense of the latest price gyrations and must provides the tools to assess future market direction.

For information on and analysis of crude oil and refined product supply and demand, inventories and international market prices, the organization needs to be fully capable to interpret and understand the market signals. This puts a demand on the quality of the trading staff and all associated functions that go with it. Access to professional information sources, online and in publications, such as Reuters, Platts, Argus, and futures market data from the largest oil futures market ; NYMEX (New York Mercantile Exchange).

Current oil markets are extremely volatile and upset by internal problems that creates fear and other elements in the already tense market environments. The sharp rise is likely at some point being reversed but timing of movement is unpredictable.



One of these crucial trading functions is the ability to buy the physical crude oil at the best possible conditions, whether on a term or a spot contract, at a fixed price or a month related average price benchmarked against a marker crude like Dubai or Brent or WTI crude.

The impact of a well informed and capable trading staff is immediately visible as explained with the purchase of a single 140.000 ton crude oil vessel where 5 $ cents per barrel price improvement already is a 50.000 USD benefit. At a yearly 6 million tons crude requirement as in Scenarios 3, 4 and 5, the benefits of just 5 cents/barrel better crude oil price negotiation are already 2.3 million USD per year benefit to the oil trading group.

A significant part of the department's activity is the continuous optimization in the crude oil type supply. All scenarios' use a mixture of sweet and sour crudes to retrieve the best possible combination of crude oil characteristics, matching the refinery unit configuration, product qualities and margin contributions. This will require a wide understanding of the variety of crude oil choices that have to be considered and of course will require contacts with all major crude oil players in the international market.

4.1.2 Risk Management Group; Price Volatility

Another important function is the mitigation of price risk. A sudden drop or rise of 5 $/barrel is quite realistic in today's environment and even the most sophisticated refinery will not be able to offset these price risks by the refiners margin. Crude oil prices need to be managed for risk with hedging of physical purchases with future contract sales to offset unwanted price risks and other methods is so common in major oil companies and large traders.

This illustrates the need for a highly qualified trading staff when yearly crude oil requirements go from current 1.3 million ton to 6.0 million ton per year. In addition there will be much more product purchase and sales activity to trade off the imbalances from the refinery output to demand yield differences.

4.1.3 Shipping/Transportation Department

Operational or shipping and transportation requirement has follow the quality of the trading groups, where as illustrated the optimization of a variety of crude oil types in the base feedstock slate for the refinery is a major contribution to a well run refinery. This will require good knowledge of shipping markets, load port conditions and the shipping brokers for best price in shipping charter parties. At 6 million ton/year the refinery will need at least 4 vessels of 140.000 tons crude per months and a variety of product vessel movement to cover the product imbalances. Similar to crude oil markets, there is a significant gain to be made by using the right vessel at the right port. Charter party (=shipping contracts) efficiency and good negotiation with shipping brokers is a cost saving.

4.1.4 Finance Department

The trading department will need an experienced back office group, where financing and payments of oil purchases are coordinated.

A typical crude oil purchase of one 140.000 ton vessel with a value of 125 million USD will govern a 30 day payment period, which for Bangladesh with a purchase of AG crude will hopefully mean an almost perfect credit term to be simultaneous with the revenue from the sold domestic refined products. Well planned working capital coordination between incoming revenue and outgoing payment can avoid large requirements for bridging working capital loans. Needless to say that in a professional environment as the international crude oil markets there will be no room for late or non payments of crude oil and product purchased.

Invoicing all refined product off takers for daily sales to the domestic markets and international sales will require a proper database supported system, which is one of the aspects covered in the study. The Petroleum Management System (PMS) is the dedicated tool for the planning of product movements on a daily basis and for distribution of products from the refinery tanks to the depots. The PMS is a tool specific designed to handle a complex oil flow in an elegant and timely manner as long as all participants cooperate with online input of all required data on a daily basis.

4.1.5 Depot Logistics Department

Staff to operate and work with the PMS as central planning tool for off take from the refinery and MI storage to the many depots in the country will be able to be more efficient and the reliability of information will improve significant than with traditional methods which should be considered to be replaced at some point in time. The PMS will warn for low depot stock levels and will alert on the need for new supplies beside many other functions that the PMS offers.

4.2 The Refinery Organization

There is a major difference in approach between the operation of a small and simple configuration like current ERL refinery is and the much larger and more modern described refineries in Scenario's 3 and 4.

Departments that will need to adapt to a different refinery are:

4.2.1 Refinery Scheduling Department

Scheduling and planning of the flow of crude oil is a very important problem in any petroleum refinery due to the potential realization of large cost savings and improved feeds. Linear programming (LP) models have been historically used in the analysis of scheduling and planning problems due to their ease of modelling and solution.

Refinery planning problems have been addressed using computational tools such as AspenTech, PIMS (Process Industry Modelling System) that are largely based on Successive Linear Programming.

Summarized: Aspen PIMS linear model overview:

- Complete linear programming optimization modelling system
- Used by over 80% of the Refinery companies and more than 65% of the Petrochemical companies worldwide
- Uses spreadsheets or database tables for data input and user-customized reporting
- Automated matrix generation for the refinery constraints and optimization objectives and reporting
- Includes process sub-model libraries for refining and petrochemicals
- Multi-case capability and comparative reporting.

However, it is difficult to model refinery operations since they involve all units operating in continuous modes along with multiple grades of crude oil (in this study represented by typical grades like Forcados, Al Shaheen, Gas condensate and Murban, Arabian light) and a variety of products all with their set minimum/maximum qualities.

Furthermore, detailed scheduling models often require a continuous time representation and a more general treatment of nonlinear equations, as well as binary variables to model discrete decisions which give rise to Mixed Integer Nonlinear Programming (MINLP) models. These models impart additional flexibility to the problem allowing the modelling of discrete decisions and constraints. Also the scheduling of vessel discharge at the SPM anchoring for pipeline transfer to the refinery poses an additional constraint on the department.

Refinery operations are complex and as emphasized the refiners margin must be positive in a real market environment to survive in the long term. Refinery scheduling is the nerve system and brain of the operation and need the best qualified staff to do this job.

4.2.2 Process Engineering Department

Stepping away from the relative simple ERL operation into a new technology driven unit configuration requires good qualified process experts to run these units.

A hydrocracker is a very complex process and demands latest generation technical education to operate the unit, likewise for the CCR unit, Isomerisation unit and Hydrodesulphurization unit. All are new to the refinery setup and need qualified staff in one central control room with latest technology instrumentation.

4.2.3 Oil Movement Department

The refinery is recommended to be located in Chittagong to take maximum advantage of the existing infrastructures, tanks, jetties, pipelines, roads, rail, port services, gas, water and electricity supply lines etc. Nevertheless the size of the refinery and number of (intermediary) product flows increases in Scenario's 3 4 and 5.

Planning of daily flows to and from units and routing to blending tanks require a professional run operation to minimize inefficiencies and product losses and or quality downgrading. The study already recommended for full efficiencies in the overall operation to use the combined storage from the current ERL refinery and all available storage tanks from the marketing organizations as one total storage facility.

This means that autonomy over the tanks, pipeline connections, pump houses and other facilities that are now separate and distinctly defined between the organizations is then coordinated by one central department. Since there are no imports, but merely imbalances and the distribution to country located depots with a major refinery operation the function of a separate storage terminal for marketing purposes in Chittagong has become less relevant and even obsolete.

Oil movement groups are responsible for the physical process to organize this now enlarged refinery product storage operation and blending processes and the distribution to jetties for inland tanker loadings.

4.2.4 Utilities Department

Gas turbines Combined Heat and Power, clean water supplies, steam production, cooling processes in any new refinery setup are entirely different from the old and inefficient technologies in current ERL. Any proper run refinery needs a reliable utility to support all unit processes and will require proper staffing.

The organization has to grow around any chosen scenario and can be everything from a lean and basic setup of a business model type of combined groups of experts to a more integrated 'major' oil company type of organization. The exact structure is an evolution process from the basic requirements that need to be part of it as described above.

Conclusions

The assessment of the current petroleum refinery activities in Bangladesh has made it clear that there are some very difficult conditions for the countries future supply and demand of petroleum products.

The future petroleum product demand had to be estimated on the basis of current and future developments with expected trends in the Bangladesh energy supply and demand. In the backdrop of decrease in natural gas supply and no real development of coal resources all projections seem to lead to increased consumption of petroleum products.

Medium term (5 years) demand will very likely be around 6 million tons per year and demand volume will then be larger than 4 times the local refinery ERL can produce and supply. This implies that ever increasing imports will then be the only way to meet demand if there is no energy supply and demand control strategy. Overall demand is also unusually high in terms of distillates and even for sophisticated and flexible refineries this is very difficult to produce a matching yield.

This major part of this Balancing, Modernisation Replacement and Expansion recommendations study describes a number of possible refinery configuration scenarios, all based on international oil market parity price and are realistic for Bangladesh.

The final conclusion of this recommendations study can be a very simple one.

If there is no implementation of overall refinery capacity expansion project then in the very near and immediate future the refined products importation will reach its maximum level possible and that will put a ceiling on further petroleum product consumption and that will act as a major hurdle to growth in Bangladesh.

Chittagong port cannot continue to handle such high movement burden even on 24 hour service, and there is no scope for other harbours in the country as these do not have the minimum required draft.

The current ERL refinery operation is not economically and financially sustainable, even with refined products valued at Singapore product parity price, due to its relatively simple configuration without conversion units and the less efficient technologies.

Furthermore there is the government administered practice to sell below market parity in the domestic market and effectively subsidising inefficient use of product consumption.

All this contributes to a large loss making operation that cannot provide its own sustainability. This cannot be acceptable neither for a state funded operation nor for a private enterprise who will not consider to participate if prices are administered with a preset loss.

Scenario 4, that is a new 100,000 bbls/day refinery complex with deep conversion technology units to be built adjacent to ERL Refinery site in Chittagong is the best and prime recommendation.

Highlights are:

- Approx. Investment of 718.2 mln USD
- Expected net refinery margin per year of 151 mln USD
- Unit configuration and expected unit costing

	mln USD
New 100.000 bbl/day CDU (incl. LPG Merox)	101.0
New 45000 bbl/day Vacuum Distillation Unit	65.4
New 5000 bbl/day Cont Regenerative reformer (CCR)	35.3
New 5000 bbl/day Isomerisation Unit	9.3
New 10.000 bbl/day Naphtha Hydrotreater	19.9
New 20.000 bbl day Hydrocracking Unit (Chevron Lummus)	161.9
New 50.000 bbl/day Hydrodesulphuriser	98.5
New 15.000 bbl/day Thermal Cracker	51.8
New Amine treatment Unit (60 ton s /day)	7.7
New Sulphur Recovery Unit (60 ton s /day)	18.4
New Hydrogen Unit (12 mmscft/day)	17.8
Gas turbine CHP unit 3*10 +7 MW/h and 450 ton/d steam.	24.9
Crude oil storage 100.000 cbm	11.5
Distillate storage 45.000 cbm	5.0
Fuel Oil storage 30.000 cbm	3.6
LPG sphere plus pressure control valve/unloading rack	3.2
Water treatment expansion 400 t/d	2.0
API oil/water separation	0.5
Flare expansion	0.2
ERL current unit refurbishments and modernisation	15.0
Investment for Scenario 4	652.9
Contingency 10%	65.3
Total estimated investment Scenario 4	**718.2**

This refinery will meet almost all required demand of all distillate products with minimum imbalances, and at a sustainable positive refinery margin while using as much as possible the existing refinery and MI storage tank infrastructure, including the SPM facility for the crude oil supply from deep draft water Kutubdia Anchoring Point.

Alternative may be a lightering procedure with large tanker of (40,000-50,000 mt) carrying capacity from Kutubdia to Sandwip Channel, Chittagong, but it should only be considered if the project is not executed or stalled.

Crude oil slate should include both low- and high sulphur type crudes in order to increase product quality and provide better overall economics.

Investments, although substantial at over 720 million USD are not unrealistically high and can be repaid from the refinery's yearly expected earnings and cash flows, and /or from governmental levied product taxation.

Growing dependency on imports from foreign supplies cannot be a justifiable strategy for energy security.

Scenario 5 is a second best option that calls for building a Grass Root Refinery of similar configuration at an entirely new location on the main land near deep water Kutubdia anchorage point, But this will require besides the refinery all oil related storage and other logistics/infrastructure to be bult. .

Costs of the civil engineering work involved for a entirely new harbour are very high and outside the scope of this study but a complete harbour facility just for oil refining alone is not justified without sharing the infrastructure with other non oil related industries, trade and warehouses, possibly LNG facilities etc.

This is a long term, (over 10 years) project and can be initiated by the private sector in partnership with the Government. Financing need is likely to exceed a billion USD.

The ultimate choice is dependent on investment capital available for the project, with the oil refining either in Chittagong or perhaps at a different location than Chittagong, with possible participation of private entrepreneurs and other parties in a domestic consumer refined product market based on international market parity price.

Obtaining the investment capital required will be difficult as commercial banks will not easily provide loans to BB- rated countries like Bangladesh, nor will the private sector step in as long as there is the current governmental dictated price regulation often well below market price level. This makes effective competition and required rate of returns uncertain.

Finance has to come from a temporary bridging loan either from the State treasury or a large bank and supported by repayment from local taxes and duties to be imposed and the refinery margin providing a positive cash flow.

There is no scope for complacency of not taking any action on enhancing refining capacity.No action is not at all an option for Bangladesh.

Appendices

Appendix 1 Crude Oil Assays And Yields

TOTAL

Crude **FORCADOS**

TBP DISTILLATION

Density at 15°C, Kg/m3		873.3
°API		30.43
Bbl/mt		7.22
Viscosity, cSt at	10 °C	17.4
	37,8 °C	
	50 °C	4.6
Pour Point, °C		-27
Paraffins wt%		
Wax Appearance Temperature °C		15
RVP at 37.8 °C, kPa		30
Water vol%		
RVP at 37.8 °C, kPa		
NaCl mg/kg		
Sulphur wt%		0.180
Mercaptan Sulphur, mg/kg		13
Hydrogen Sulphide, mg/Kg		0
Acidity, mg KOH/g		0.34
Nickel, mg/Kg		3.9
Vanadium, mg/Kg		1.0

Country Nigeria

Assay Date 1-Feb-02

	%Pds	%Vol
Ethane	0.03	0.07
Propane	0.23	0.40
Iso-Butane	0.21	0.33
n-Butane	0.34	0.51

°C	wt%	vol%	°C	wt%	vol%
080	3.80	4.74	450	80.87	82.94
140	10.86	12.89	475	83.72	85.56
150	12.25	14.45	500	86.35	87.94
160	13.66	16.02	525	89.06	90.36
180	16.62	19.27	550	92.15	93.11
200	19.96	22.83	565	94.20	94.94
220	23.88	26.92			
240	28.58	31.72			
250	31.23	34.40			
260	34.05	37.23			
300	46.30	49.41			
310	49.46	52.53			
320	52.60	55.62			
330	55.69	58.65			
340	58.69	61.59			
350	61.58	64.41			
360	64.32	67.08			
370	66.89	69.58			
380	69.25	71.87			
390	71.40	73.94			
400	73.35	75.82			

PROPERTIES OF TBP CUTS

LIGHT NAPHTHA	Cuts	Yield	Yield	Den 15°C	S	RSH	RON	RON	MON	MON	Napht	Aro	RVP			
	°C	wt%	vol %	Kg/m3	wt%	mg/kg	clear	0,15 g/l	clear	0,15 g/l	vol%	vol%	kPa			
	15-65															
	15-80	2.99	3.81	685	0.0011		76.7	83.4	73.8	79.5		1.9				
HEAVY NAPHTHA	Cuts	Yield	Yield	Den 15°C	S	RSH					Napht	Aro.				
	°C	wt%	vol %	Kg/m3	wt%	mg/kg					vol%	vol%				
	80-150	8.45	9.71	760	0.0042						52.8	12.5				
	80-175	12.08	13.72	769	0.0091						51.2	14.2				
	100-150	6.10	6.99	761	0.0088											
KEROSENE	Cuts	Yield	Yield	Den 15°C	S	RSH	Smoke	Acidity	Cetane	Freeze Pt	Naphta	Aro.	Saybolt	Visc cSt		Flash
	°C	wt%	vol %	Kg/m3	wt%	mg/kg	Point	mg/g	calc	°C	vol%	vol%	Color	50°C		Point
	150-230	13.98	14.87	821	0.062		18			-66.0		15.6				
	175-230	10.35	10.86	832	0.071											
	150-250	18.98	19.95	831	0.069											
GASOIL	Cuts	Yield	Yield	Den 15°C	S		Anilin	Cetane	Cetane	Cloud Pt	CFPP	Pour Pt	Visc cSt	Visc cSt	KUOP	Flash
	°C	wt%	vol %	Kg/m3	wt%		Point °C		calc	C	C	C	50°C	100°C		Point
	175-400	57.47	57.36	875	0.122				44	-3	-5	-7				
	230-400	47.12	46.50	885	0.142				45	-1	-3	-5				
	230-375	41.84	41.41	882	0.132				44	-9	-11	-13				
VACUUM DISTILLATE	Cuts	Yield	Yield	Den 15°C	S	Conrad.	Anilin	Ni	V	Total N	Bas N	Pour Pt	Visc cSt	Visc cSt	KUOP	Asp C7
	°C	wt%	vol %	Kg/m3	wt%	wt%	Point °C	mg/kg	mg/kg	wt%	mg/kg	C	100°C	150°C		wt %
	375-550	24.08	22.39	939	0.26	0.13				0.1576					11.63	
	375-565	26.13	24.22	942	0.28											
	375-580															
	400-580															
RESIDUE	Cuts	Yield	Yield	Den 15°C	S	Conrad.	AsphC5	Ni	V	Total N	Pene	Pour Pt	Visc cSt	Visc cSt		Asp C7
	°C	wt%	vol %	Kg/m3	wt%	wt%	wt%	mg/Kg	mg/kg	wt%		C	100°C	150°C		wt%
	> 375	31.93	29.28	953	0.34							21	25			
	> 550	7.85	6.89	995	0.56	16.2				0.4899		54	798			0.1
	> 565	5.80	5.06	1001	0.61								1222			
	> 580															

Total DTS/AM Sep-03

TOTAL

MURBAN

TBP DISTILLATION

Country	Abu Dhabi
Assay	01-Mar-02

Density at 15 °C, kg/m3	826.6
° API	39.60
Bbl/mt	7.62
Viscosity, cSt at 10 °C	5.9
Viscosity cst at 50°C	2.4
Pour Point, °C	-12
Paraffins, wt%	
Wax Appearance Temp °C	
R V P at 37.8 °C, kPa	40.7
Water %vol	
BSW %vol	
NaCl mg/kg	
Sulphur, wt %	0.730
Mercaptan sulphur, mg/kg	58
Hydrogen sulphide, mg/kg	15
Acidity mg KOH/g	0.056
Nickel, mg/Kg	4.3
Vanadium, mg/Kg	2.6

	wt %	vol %
Ethane	0.00	0.00
Propane	0.02	0.03
Iso-Butane	0.05	0.07
n-Butane	0.23	0.33

°C	wt %	vol %	°C	wt %	vol %
015	0.30	0.50			
100	10.83	13.53			
180	26.96	31.32			
250	41.36	46.16			
350	59.44	63.85			
450	77.13	80.25			
550	92.71	93.96			

Cumulative volume yields given after substraction of volume expansion

PROPERTIES OF TBP CUTS

LIGHT NAPHTHA	Cut °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %	RSH %wt	RON clear	RON 0,15g/l	MON clear	MON 0,15g/l	Napht %vol	Aro %Vol	RVP kPa			Benz %vol
	15-65															
	15-80	7.63	9.57	659	0.0464		69.0	76.7	66.3	74.0		1.2				1.2
HEAVY NAPHTHA	Cuts °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %						Napht %vol	Aro %vol				
	80-150	12.51	14.24	726	0.0893						20.2	18.2				
	80-175	18.02	20.14	740	0.0900						16.3	17.7				
	100-150	9.61	10.78	737	0.1049						16.3	17.8				
KEROSENE	Cuts °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %	RSH mg/kg	Smoke Point	Acid. mg/g	Cetane Calc	Freeze Pt °C	Naphtal. %vol	Aro. %vol	Saybolt Color	Visc cst 50 °C		Flash Point
	150-230	16.81	17.60	789	0.146		25		44.5	-52.8		21.1				
	175-230	11.29	11.71	797	0.173				46.6							
	150-250	20.92	21.84	792	0.153				47.8							
GASOIL	Cuts °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %		Anilin Pt C	Cetane	Cetane Calc.	Cloud Pt °C	CFPP °C	Pour Pt °C	Visc cst 50 °C	Visc cst 100 °C	KUOP	Flash Point
	175-400	42.49	42.10	834	0.580				56.5	-18.5		-22.5				
	230-400	31.20	30.39	849	0.727				55.7	-12.4		-16.4				
	230-375	26.62	26.03	845	0.681				55.1	-11.6		-15.6				
VACUUM DISTILLATE	Cuts °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %	Conrad wt %	Anilin Pt C	Ni mg/kg	V mg/kg	Total N wt %	Bas N wt%	Pour Pt C	Visco cSt 100 °C	Visc cst 150°C	KUOP	Asp. C7 %wt
	375-550	28.85	26.02	917	1.25	0.11				0.0200					11.92	
	375-565															
	375-580															
	400-565															
RESIDUE	Cuts °C	Yield wt %	Yield vol %	Dens 15°C kg/m3	S wt %	Conrad wt %	Asp C5 %wt	Ni mg/Kg	V mg/Kg	Total N wt %	Pene	Pour Pt °C	Visco cSt 100 °C	Visco cSt 150 °C		Asp. C7 wt %
	> 375	36.14	32.05	932	1.34			14.7	12.0			18	6	2		
	> 550	7.29	6.04	998	1.62	13.8		33.5	28.0	0.2372		35	200	36		2.2
	> 565															
	> 580															

* estimated value

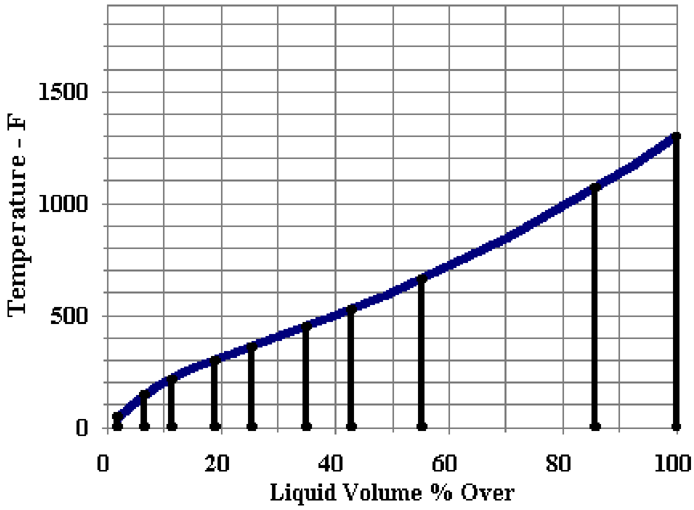
Total DTS/AM May-02

Arab Light | **Saudi Arabia** | **arablt** | **22-Dec-97**

Crude Oil Assay
PetroPlan Format

API	Calc	34.0
SG	Calc	0.8547
Total Sulfur - wt%	Calc	1.78
Total Nitrogen - wt	Calc	0.07
Nickel ppm	Calc	4.37
Vandium ppm	Calc	20.18

Boiling Curve At Std lv% Fractions	0	13
	2	53
	5	112
	10	202
	15	259
	20	308
	30	402
	40	497
	50	597
	60	720
	70	843
	80	987
	90	1133
	95	1212
	98	1265
	100	1300



Description	arablt									
Temp Msr(F or C)	F									
Basis(Wt or Vol)	V									
% C2 in crude	0									
% C3 in crude	0.4									
% IC4 in crude	0.2									
% NC4 in crude	1.2									
Cut Name (x)	LSR	LtNap	MedNap	HvNap	Kero	LtDsl	HvDsl	Gasoil	Pitch	
Cut Initial Temp (x		160	220	300	360	450	525	650	1050	
Cut final temp	160	220	300	360	450	525	650	1050	1300	
Yld on crude,%	4.78	4.74	7.62	6.51	9.67	7.90	12.37	30.36	14.25	
SG	0.6661	0.6974	0.7407	0.7706	0.7968	0.8232	0.8518	0.9218	1.0229	
API	80.9	71.4	59.5	52.1	46.1	40.4	34.6	22.0	6.8	
Sulfur	0.0235	0.0252	0.0301	0.0516	0.1600	0.6300	1.1900	2.5100	4.3500	
RON	58.2	50.0	36.8	30.7						
MON										
Aromatics,%		6.6	12.7	17.6	21.8	25.3				
Naphthenes,%		12.9	18.6	20.5						
Smoke pt,mm					22.3	19.3				
Freeze point					-47.0	-8.0				
Pour point					-57.0	-22.0	18.0	88.0	115.0	
Cetane No					49.4	53.0	52.8			
Aniline point				133.9	141.0	151.3	161.0	177.3		
CS at 122F					1.21	1.82	3.52	37.69	110392	
CS at 210F					0.93	1.09	1.56	6.69	1663	
Nitrogen,%	0.0000	0.0000	0.0000	0.0001	0.0005	0.0018	0.0065	0.0583	0.2980	
Nickel,ppm								0.05	25.50	
Vanadium,ppm								0.12	118.10	
C5 insoluble,%									12.30	
Concarbon,%								0.77	20.30	
Property A (v)										
Property B (v)										
Property X (w)										
Property Y (w)										
Calulated K		12.42	12.10	11.99	11.96	11.93	11.92	11.87	11.52	

LABORATORY REPORT NO. - FUJ/FCA1025/06

Al Shaheen Crude Oil Ex Qatar sampled on 10th April 2006.

CRUDE OIL - DETAILED ASSAY ALL CUTS OVERVIEW

TEST	UNIT	METHOD	Whole Crude	CUT RANGE 1 LIGHT ENDS - C4-	2 C5 - 65°C	3 65 - 150°C	4 150 - 200°C	5 200 - 250°C	6 250 - 300°C	7 300 - 350°C	8 350 - 420°C	9 420 - 560°C	10 560°C +
Distillation of Crude Oil (15 plate)													
Yield	% Wt.	ASTM D 2892 & ASTM D 5236		1.28	2.70	7.23	6.39	7.65	9.27	9.37	12.03	21.10	22.98
Yield	% Vol.			2.00	3.70	8.77	7.19	8.23	9.59	9.44	11.77	19.81	19.50
Cum. Yield	% Wt.	ASTM D 2892 & ASTM D 5236		1.28	3.98	11.21	17.60	25.25	34.52	43.89	55.92	77.02	100.00
Cum. Yield	% Vol.			2.00	5.70	14.47	21.66	29.89	39.48	48.92	60.69	80.50	100.00
Density @ 15°C	kg/L	ASTM D 5002 / IP 365 / IP 190	0.8868		0.6464	0.7316	0.7897	0.8250	0.8578	0.8803	0.9052	0.9449	1.0250
Specific Gravity @ 60/60° F		Conversion	0.8873		0.6465	0.7318	0.7901	0.8254	0.8583	0.8808	0.9057	0.9455	1.0257
API Gravity @ 60° F		Calculated	27.97		87.37	61.86	47.59	39.93	33.36	29.15	24.73	18.16	6.45
Density @ 15°C (dry)	kg/L	Calculated	0.8865										
Specific Gravity @ 60/60° F (dry)		Conversion	0.8870										
API Gravity @ 60° F (dry)		Calculated	28.03										
Water Content	% Vol.	ASTM D 4298	0.18										
Light Ends													
methane	% mass	GC	0.000										
ethane			0.039										
propane			0.309										
i-butane			0.260										
n-butane			0.811										
Total C1-C4			1.419										
i-pentane			0.950										
n-pentane			0.633										
Sulphur Content	% mass	ASTM D 4294	2.37		0.043	0.066	0.180	0.356	1.04	1.88	2.41	2.86	5.00
Mercaptan Sulphur	mg/kg	ASTM D 3227			235	314	225	103	54				
Mercaptan Sulphur	mg/kg	UOP 163	339										
Total Nitrogen	% mass	ASTM D 5291 (Mod)	0.15						< 0.05	< 0.05	0.08	0.15	0.37
Research Octane Number ***		ASTM D 2699			74.2	57.0							
Motor Octane Number ***		ASTM D 2700			71.0	55.0							
PIONA analysis	% Vol	GC											
Total paraffins					95.32	61.63	33.72						
Total olefins					< 0.01	< 0.01	< 0.01						
Total napthenes					4.65	36.24	23.61						
Total aromatics					0.03	2.13	18.23						
> 200° C & Unidentified					< 0.01	< 0.01	24.44						
Poly-N					< 0.01	< 0.01	5.97						
Aniline Point	° C	ASTM D 611					55.2	58.4	60.4	68.6	73.0	84.6	
Smoke Point	mm	IP 57					27.0	21.0					
Naphthalene content	%Vol.	ASTM D 1840					0.17						
Vanadium (V)	mg/kg	IP 470 (AAS)											112
Nickel (Ni)													38
Iron (Fe)													15
Nickel / Vanadium Ratio													0.34
Freeze Point	° C	ASTM D 2386					Below -70.0	- 52.5					
Cloud Point	° C	ASTM D 2500						Below -42	- 29	- 4	+ 18	##	
Pour Point (upper)	° C	ASTM D 5853 / D97	Below -45						- 30	- 6	+ 15	+ 42	+ 51
Pour Point (lower)	° C	ASTM D 5853 / D97	Below -45										
Kinematic Viscosity @ 20° C	mm^2/S	ASTM D 445	44.06										
Kinematic Viscosity @ 40° C			13.32					1.670	3.069	6.438	16.23		
Kinematic Viscosity @ 50° C			10.21					1.443	2.531	4.977	11.46	74.55	
Kinematic Viscosity @ 80° C									1.629	2.640	5.068	21.06	
Kinematic Viscosity @ 100° C												11.53	3013
Kinematic Viscosity @ 150° C													193.9
Distillation	° C	ASTM D 86						See page 17	See page 17	See page 17	*		
Cetane Index		ASTM D 976						43.3	45.8	46.8	*		
Refractive Index @ 20° C		ASTM D 1218						1.4578	1.4771	1.4893			
Refractive Index @ 70° C		ASTM D 1218	1.5008										
Micro Carbon Residue	% mass	ASTM D 4530										0.60	23.3
Asphaltene	% mass	IP 143	1.70										9.02
Total Acid Number	mgKOH/g	ASTM D 664	0.329										
Benzene Content	% mass	GLC	< 0.01										
Salt Content	PTB	ASTM D 3230	46.3										
Salt Content as NaCl	mg/L	IP 265	145.8										
Salt Content	mg/kg	IP 265	149.0										
Flash Point	° C	ASTM D 93 (Mod.)	Below -5										
Sediment by Extraction	% mass	ASTM D 473	0.01										
Reid Vapour Pressure @ 100° F	psi	ASTM D 323	6.4										
Hydrogen Sulphide	mg/kg	UOP 163	< 1										
Mercury	mg/kg	Cold Vapor	< 1										
Lead	mg/kg	ASTM D 5863 / AAS	< 0.1										
Wax Content prec. At -30° C	% mass	UOP 46	1.0										

Note: * Unable to perform test due to the heavy nature of the fraction.
*** Samples were blended with ASTM grade Iso Octane, and results were calculated from the blend's result.
Unable to test due to the dark colour of the fraction

EASTERN REFINERY LIMITED
Quality Control Department
CHITTAGONG

Dated : 24th September'20

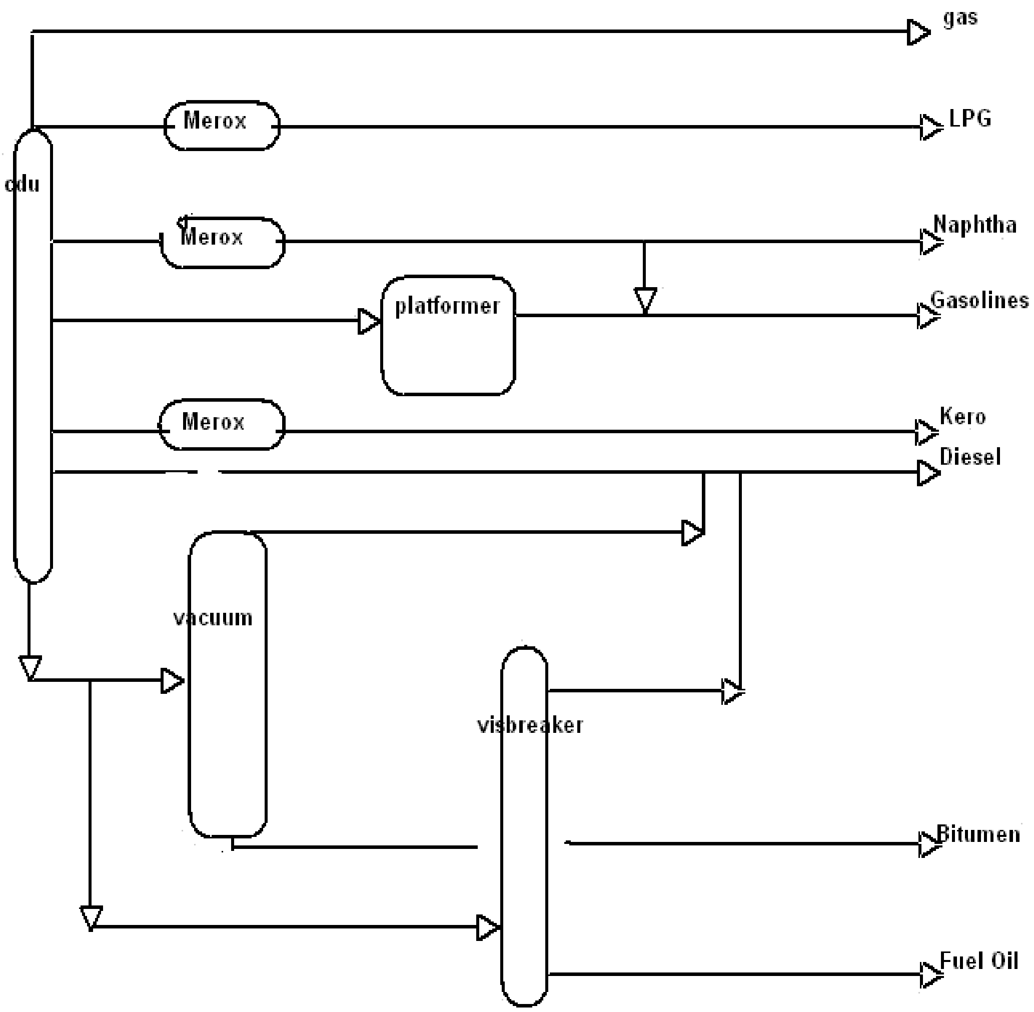
TEST REPORT OF CONDENSATE COLLECTED FROM DIFFERENT GAS FIELDS

Test	Method	RESULTS			
		Jalalabad 16.01.2001	Sangu 11.9.2001	Rashidpur 26.04.2001	Kailashtilla 11.09.2001
1. Density at 15°C, Kg/L	ASTM D 1298	0.7739	0.8845	0.8059	0.7864
2. R. V. P. at 38°C, Psi.	ASTM D 323	8.3	1.5	3.3	6.2
3. Colour, ASTM	ASTM D 1500	-	2.0	-	-
Saybolt	ASTM D 156	+30	-	+17	+21
4. Flash Point, (Abel), °F	IP 170	<50	<50	<50	<50
5. Doctor Test	ASTM D 235	Negative		Positive	Negative
6. RSH, PPm	UOP 163	-			-
7. Total Sulphur, % Wt.	ASTM D 4294	0.085	0.055		0.011
8. Pour Point, °C	ASTM D 97	<0	<0	<0	<0
9. Distillation, °C	ASTM D 86				
IBP		45	92	70	50
10%		80	112	92	87
20%		92	119	98	98
30%		102	126	106	105
40%		115	137	114	113
50%		119	149	127	125
60%		130	169	145	135
70%		145	198	178	153
80%		167	247	217	184
90%		212	284	261	239
95%		250	312	286	275
FBP		275	353	321	304

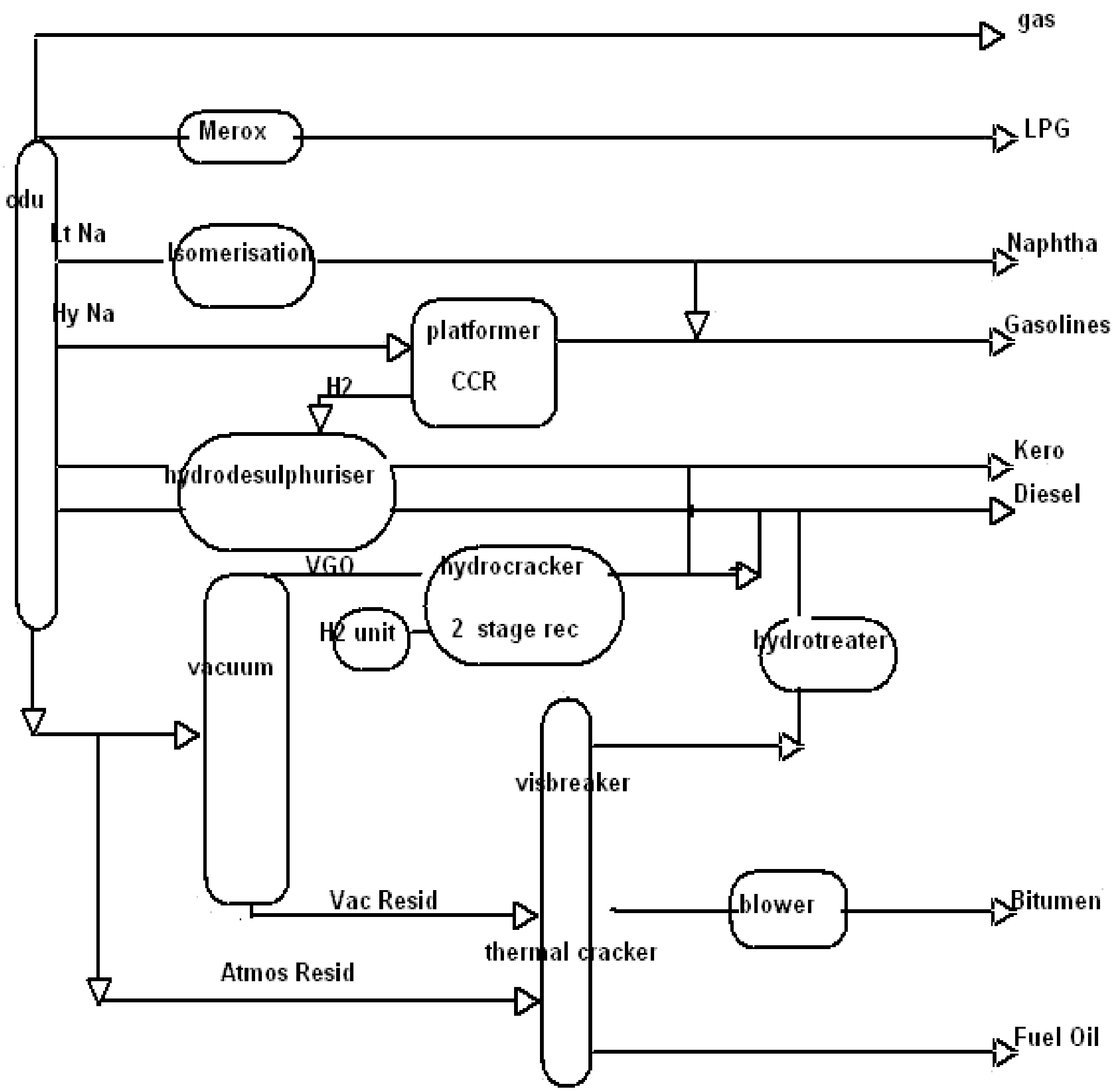
(A S M MAHBUBUL ALAM)
Quality Control Officer

Appendix 2 Refinery flow sheets

ERL current configuration (simplified)



Scenario 4 configuration (simplified)



Appendix 3: Technology discussion

From: Rogers, Jason (Jay.Rogers) [mailto:Jay.Rogers@chevron.com]

Sent: 05 March 2011 01:00

To: gjk-51@tiscali.co.uk

Cc: Bhattacharya, Subhasis (SBhattacharya); Dirstine, Julie (JulieC)

Subject: RE: Bangladesh HCR request

Dear Gerard,

Thanks for your inquiry to CLG. For the application you mention, a hydrocracker would be very suitable for making high quality diesel and kero. CLG has a lot of experience in hydrocracking Middle East VGO feedstocks such as Arab Lt and Murban. CLG is the world leader in mid-distillate selective, high conversion hydrocracking.

CLG has experience designing Single Stage Recycle (SSREC), Two Stage Recycle (TSR), and Single Stage Reaction Sequenced (SSRS) configurations that can be applied. The SSREC requires some bleed (eg 5%), where the other configurations can run at full conversion with the provisions for a minor bleed at EOR. At high conversion these units make very high smoke point jet and very high cetane diesel, with a high yield of total mid distillates.

The Total Investment Cost for the HCR and H2 unit is likely about $150 MM.

We hope this helps in your evaluation and planning work.

Best regards,

Jay

Jay Rogers, Licensing Manager

Chevron Lummus Global, LLC

100 Chevron Way / Building 10, Room 3348 / Richmond CA 94801

Tel +1 510 242 5935 Fax +1 925 842 1412

mail to jay.rogers@chevron.com

Typical Hydrocracker yield/properties

(Shell Global Solutions)

Phase 1: HCU

User	UoM	Feed	H2	H2S	FG	LPG	HC Tops	HC Na	HC Kero	HC GO	Hydrowax
Yield	(wt %)	100	-2,16	1,39	0,46	2,78	6,6	12,42	29,44	46,62	2
Average Boiling Point	(°C)	392,76									
Specific Gravity	(-)	0,893	0,07	0,802	0,14	0,548	0,67	0,738	0,792	0,836	0,841
Cetane Number	(-)	55,54							41,53	57,77	58,45
Aromatics (UV) Tri	(wt %)	2,62									0,19
Vanadium	(ppm wt)	1,76	0				0	0			0
Basic Nitrogen	(ppm wt)	323,63	0				0	0			0
Cloud Point	(°C)	18,71							-68,43	-10,8	26,74
Smoke Point	(mm)	12,63							28,48	0	0
Total Aromatics (PONA)	(wt %)					0	1,93	6,15			
Nickel	(ppm wt)	0,9	0				0	0			0
C7 Asphalthenes	(wt %)	0,25	0				0	0			
Freeze Point	(°C)	19,4							-59,13	0	0
RVP_bar	(Bara)					7,47	0,84	0			
PourPoint	(°C)	17,55				-163,83	-123,28	0	-73,43	-15,8	21,74
Aromatics (UV) Mono	(wt %)	4,89									1,11
Total Paraffins (PONA)	(wt %)					100	78,96	52,7			
Con. Carbon	(wt %)	0,72	0				0	0	0	0	0
RON	(-)					103,48	74,71	57,91			
Aromatics UV Tetra+	(wt %)	2,45									0,14
Sulphur	(ppm wt)	13070,39				0	0	0,12	0,23	0,53	1,51
Aromatics (UV) Di	(wt %)	3,24									0,18
Total Naphthenes (PONA)	(wt %)					0	19,11	41,16			
Total Nitrogen	(ppm wt)	1105,71	0				0	0			
VBI	(-)	20,65	-60				-15,72	0	0,11	10,89	20,47
Total Acid Number	(-)	0,11							0	0	0
MON	(-)					96,62	73,48	56,49			
Hydrogen Content	(wt %)	12,53									
Carbon Content	(wt %)	86,05									
Aromatics	(vol %)	18,26				0	1,47	0	0	0	0
propane	(wt %)					32,25	0	0			
iso-butane	(wt %)					43,84	0,38	0			
n-butane	(wt %)					23,87	5,14	0			
iso-pentane	(wt %)					0,03	20,07	0			
n-pentane	(wt %)					0	10,02	0			
cyclopentane	(wt %)					0	0,01	0			
n-hexane	(wt %)					0	34,42	4,95			
methyl cyclopentane	(wt %)					0	4,5	1,78			
2,2-dimethylpentane	(wt %)					0	0	0			
benzene	(wt %)					0	1,3	0,88			
cyclohexane	(wt %)					0	3,2	1,27			
C7P	(wt %)					0	0	16,57			
C7N	(wt %)					0	11,4	11,73			
C8A	(wt %)					0	0	2,21			
n-heptane	(wt %)					0	3,5	0			
toluene	(wt %)					0	0,62	2,95			
C8P	(wt %)					0	0	19,53			
C9P	(wt %)					0	0	11,64			
C9A	(wt %)					0	0	0,31			
C8N	(wt %)					0	0	18,31			
C9N	(wt %)					0	0	8,07			
iC5 (wt%)	(wt %)					0	22,2	0			
RVP kPa	(kPa)					746,81	84,29	0			
CCAI	(-)	806,02					736,15	738,41	791,78	790,31	754,84
Visc. 50°C	(cSt)	11,67				0,24	0,38	1	1,01	2,82	11,48
Sulphur	(wt %)	1,31	0	94,08			0	0	0	0	0
Benzene	(vol %)					0	0,99	0,57			
Cetane 2-point	(-)	42,47							41,27	54,96	56,53
Visc. 40°C	(cSt)	16,29							1,15	3,43	15,7
Net Cal Value	(TSRF/T)	1,04	2,96		1,84	1,13	1,11	1,09	1,08	1,07	1,07
ASTM IBP	(°C)	210,88				-31,82	38,13	84	152,65	235,91	346,34
ASTM 5%	(°C)					-31,82	39,13	94,31			
ASTM 10%	(°C)	267,22				-31,82	38,13	99,86	165,04	254,45	376,52
ASTM 30%	(°C)		0				41,18	101,55			
ASTM 50%	(°C)	378,89				-11,25	59,15	111,86	186,13	284,39	412,48
ASTM 90%	(°C)	533,69				-4,46	81,67	129,77	217,56	339,23	506,51
ASTM 95%	(°C)	549,89				-4,23	90,68	137,97	229,87	354,11	526,36
ASTM FBP	(°C)	570,94				-4,06	103,45	149,47	246,39	373,18	550,32
Flash	(°C)	90,81				-98,33	-46,3	-1,42	43,62	102,46	173,34
Visc. 100°C	(cSt)						0,28	0,6			3,69
EVAP 70 °C	(vol %)					100	73,37	0			
EVAP 100 °C	(vol %)					100	100	10,6			
EVAP 150 °C	(vol %)					100	100	100			
EVAP 250 °C	(vol %)	6,32							100	6,62	0
EVAP 350 °C	(vol %)	39,02							100	94,06	0,31
EVAP 370 °C	(vol %)	46,63							100	99,51	7,1
EVAP 300 °C	(vol %)	20,09							100	65,01	0
EVAP 357 °C	(vol %)	41,69							100	96,36	1,81
EVAP 120 °C	(vol %)					100	100	78,5			
Yield	(vol %)	100	-27,49	1,55	2,93	4,52	8,79	15,02	33,17	49,78	2,12
Total Metals	(ppmwt)	2,67									0
CFPP	(°C)	18,13							-67,43	-9,8	27,74

Appendix 4 Mass Balances

Scenario 4	Murban	0.827	0.73	39.60036						htu na	67	50.4%
		7.605804								htu dies	79	59.4%
mbpd	133	49	0	5	0	20	0	25	5			
	cdu	vdu	bit	ccr	hrc	mhc	fcc	vbu	isom	recycle stream	**Yield %wt**	
ref gas	0.9%			7.0%	4.6%	1.7%	3.0%	2.0%	1.8%		1.9%	
propane	0.4%			1.3%	0.0%	1.0%	5.3%				0.6%	
butane	0.6%			3.7%	0.0%	1.0%	5.7%		0.0%		0.9%	
lvn	8.7%				1.7%	6.0%			-100.0%		5.8%	
hvn	7.3%			-100.0%	3.2%	7.0%		1.8%			4.9%	
reformate/alk				88.0%			48.0%	0.0%	0.0%		3.3%	
Isomerate									95.0%		3.6%	
lt kero	10.6%										10.6%	
jet	13.8%				9.0%	21.0%					17.0%	
diesel	20.1%				10.4%	55.0%	23.0%	21.0%			32.3%	
hy gasoil	6.0%										6.0%	
lsvgo		48.9%	0.0%		31.4%	-100.0%	-100.0%	0.0%		0.0%	3.0%	
hsvgo								0.0%			0.0%	
lsatres											0.0%	
hsatres	31.6%	-100.0%	0.0%		-50.0%			0.0%			-5.2%	
vac resid		49.7%	-100.0%		-50.0%			-100.0%			-0.5%	
bitumen			90.0%								0.0%	
lsfo					37.5%	3.8%		0.0%		0.0%	0.6%	
hsfo			10.0%				9.0%	75.0%			14.1%	
sulph					0.4%	0.8%					0.1%	
cons/loss	0.0%	1.4%	0.0%	0.0%	1.8%	2.7%	6.0%	0.0%	3.2%		1.0%	
	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.2%	0.0%		100.0%	

Scenario 4	ar lt	0.855	1.8	33.99708							htu na	67
sg		7.356725									htu dies	79
mbpd	133	49	8	5	0	20	0	25	5			
	cdu	vdu	bit	ccr	hrc	mhc	fcc	vbu	isom	recycle stream	**Yield %wt**	
ref gas	0.7%			7.0%	4.6%	1.7%	3.0%	0.0%	1.8%		1.3%	
propane	0.4%			1.3%	0.0%	1.0%	5.3%				0.6%	
butane	0.4%			3.7%	0.0%	1.0%	5.7%		0.0%		0.7%	
lvn	7.3%				1.7%	6.0%			-100.0%		4.5%	
hvn	8.6%			-100.0%	3.2%	7.0%		2.0%			6.3%	
reformate/alk				88.0%			48.0%	0.0%	0.0%		3.3%	
Isomerate									95.0%		3.6%	
lt kero	4.2%										4.2%	
jet	12.6%				9.0%	21.0%					15.7%	
diesel	17.8%				10.4%	55.0%	23.0%	21.0%			30.0%	
hy gasoil	3.8%										3.8%	
lsvgo		40.0%	0.0%		31.4%	-100.0%	-100.0%	0.0%		18.8%	-0.3%	
hsvgo											0.0%	
lsatres	0.0%	0	0.0%		0.0%			0.0%			0.0%	
hsatres	44.1%	-100.0%	0.0%		-50.0%			-100.0%			-11.5%	
vac res		58.6%	-100.0%		-50.0%			0.0%			15.6%	
bitumen			90.0%								5.4%	
lsfo		0.0%			37.5%	3.8%		0.0%		-18.8%	0.6%	
hsfo			10.0%				9.0%	77.0%			15.1%	
sulph					0.4%	0.8%					0.1%	
cons/loss	0.0%	1.4%	0.0%	0.0%	1.8%	2.7%	6.0%	0.0%	3.2%		1.0%	
	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		100.0%	

Scenario 4	condensate	0.784	0.011	48.98469							
sg		8.022959				22???					
mbpd	133	0	0	5	0	0	0	0	5		
	cdu	vdu	lub	ccr	hrc	mhc	fcc	vbu	isom	recycle stream	**Yield %wt**
ref gas	0.0%			5.1%	4.6%	1.7%	3.0%	2.0%	1.8%		0.3%
propane	0.0%			3.2%	0.0%	3.0%	5.3%				0.1%
butane	0.0%			3.7%	0.0%	3.5%	5.7%		0.0%		0.1%
lvn	29.0%				1.7%	13.5%			-100.0%		25.2%
hvn	41.0%			-100.0%	3.2%	9.8%		8.0%			37.2%
reformate/alk				88.0%			48.0%	0.0%	0.0%		3.3%
isomerate									95.0%		3.6%
lt kero											0.0%
jet/kero	12.0%				9.0%	19.0%					12.0%
diesel	17.8%				10.4%	42.0%	23.0%				17.8%
hy gasoil	0.0%										0.0%
lsvgo		45.0%	32.0%		31.4%	-100.0%	-100.0%	10.0%		18.8%	0.0%
hsvgo											0.0%
lsatres	0.0%	-100.0%	-100.0%		-50.0%						0.0%
hsatres											0.0%
vacres		53.6%	0.0%		-50.0%			-100.0%			0.0%
luboil			45.0%								0.0%
lsfo					37.5%	4.0%		78.0%		-18.8%	0.0%
hsfo			19.5%				9.0%				0.0%
sulph					0.4%	0.8%					0.0%
cons/loss	0.2%	1.4%	3.5%	0.0%	1.8%	2.7%	6.0%	2.0%	3.2%		0.3%
	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		100.0%

Scenario 4	Forcados	0.873	0.18	30.58477							
		7.20504									
mbpd	133	49	0	5	0	20	0	25	5		
	cdu	vdu	lub	ccr	hrc	mhc	fcc	vbu	isom	recycle stream	**Yield %wt**
ref gas	0.0%			2.1%	4.6%	1.7%	3.0%	2.0%	1.8%		0.8%
propane	0.2%			3.2%	0.0%	1.0%	5.3%				0.5%
butane	0.6%			3.7%	0.0%	1.0%	5.7%		0.0%		0.8%
lvn	3.0%				1.7%	6.0%			-100.0%		0.1%
hvn	8.5%			-100.0%	3.2%	7.0%		8.0%			7.2%
reformate/alk				85.0%			48.0%	0.0%	0.0%		3.2%
isomerate									95.0%		3.6%
lt kero											0.0%
jet	14.0%				9.0%	21.0%					17.1%
diesel	41.8%				10.4%	55.6%	23.0%	10.0%			52.1%
hy gasoil											0.0%
lsvgo		48.6%	32.0%		31.4%	-100.0%	-100.0%	0.0%		18.8%	2.9%
hsvgo											0.0%
lsatres	31.6%	-100.0%	-100.0%		-50.0%			0.0%			-5.2%
hsatres											0.0%
vacres		50.0%	0.0%		-50.0%			-100.0%			-0.4%
bitum/lub			45.0%								0.0%
lsfo					37.5%	3.8%		78.0%		-18.8%	15.2%
hsfo			19.5%				9.0%				0.0%
sulph					0.4%	0.2%					0.0%
cons/loss	0.3%	1.4%	3.5%	6.0%	1.8%	2.7%	6.0%	2.0%	3.2%		1.9%
	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		100.0%

Appendix 5: Furnace, Unit, Utility Consumption Estimates

Scenario 4
Consumption/loss

Furnace Capacities, Steam, water

unit cap bbls/day		steam Ton 300psi/day	power MWh	cooling water cbm/day	fuel to furnace kJ	H2 Mscf	furnace kw/day	(Calculated) Energy to Furnaces Fuel tons/day required	(Calculated) furnace MWh net capacity required	furnace Kcal/h heat duty capacity actual	furnace MWh gross capacity actual	Estimated furnace efficiency
133000	CDU	598.5	5.0	77140.0	7015750000.0	0.0	1948819.6	149.9	81.2	81685297	95.0	85.5%
45000	ABP(VDU)	202.5	0.6	25650.0	1424250000.0	0.0	395625.0	30.4	16.5	17196905	20.0	82.4%
25000	SCP(VBU+Th CR)	350.0	1.3	6500.0	3692675000.0	0.0	1025743.1	78.9	42.7	42992261	50.0	85.5%
5000	CCR 102+Isom	67.5	0.6	11500.0	1582500000.0	-40000.0	439583.4	33.8	18.3	21496131	25.0	73.3%
20000	HCU+H2	50.0	1.3	34000.0	4500000000.0	40000.0	1250000.1	96.2	52.1	51590714	60.0	86.8%
45000	HDS	112.5	1.9	85500.0	1710000000.0	22500.0	475000.0	36.5	19.8	19776440	23.0	86.1%
	total units	1381.0	10.6	240290.0	19925175000.0	22500.0	5534771.3	425.8	230.6		273.0	84.5%

Fuel Consumption as %wt Crude intake: 2.34%

ERL		**Electr use MWh**	**steam use ton/hr**
Main Process units		5.0	24.9375
SRU, Amine, HDS,H2		7.0	
power/steamplants/bio		3	
bitumen	actual	0.2	
tank farm/jetty/flare	estimate	2	
min backup required		7	
Total Scen4		**24.2**	
Nat Gas import	Ncbm/y	35640000	
in liquid oil equiv	ton/day		79.0
Gas as % Crude intake			0.43%

Scen 4 **Power unit**		**fuel use per hour**	**Electr output MWhr**	**steam output ton/hr**	Estimated **turbine efficiency**
Gasturbine CHP1	Gas Ncbm/hr	1500	10.00	20.0	66.7%
Gasturbine CHP2	Gas Ncbm/hr	1500	10.00	20.0	66.7%
Gasturbine CHP3	Gas Ncbm/hr	1500	10.00	20.0	66.7%
totals		4500	30.00	60.0	
	per day	108000	720.00	1440.0	