Bangladesh

Asian Development Bank

STRENGTHENING OF THE HYDROCARBON UNIT IN THE ENERGY AND MINERAL RESOURCES DIVISION (PHASE-II)

PETROLEUM REFINING & MARKETING

RFP HCU/CS-06

ASSESSMENT REPORTS

December 2010
C1334

SOFRECO

Société Française de Réalisation, d'Etudes et de Conseil
92-98, boulevard Victor Hugo 92115 Clichy Cedex - France
Tél : +33 1 41 27 95 95 - Fax : +33 1 41 27 95 96
E-mail : infra@sofreco.com - Site Web : www.sofreco.com

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Management Consulting
SRG Bangladesh Limited

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EXECUTIVE SUMMARY

STRENGTHENING OF THE HYDROCARBON UNIT: STUDY ON PETROLEUM REFINING AND MARKETING is a comprehensive study project on the Petroleum Downstream Sector. This study project is broadly divided into two phases: 1st phase is the Assessment of Refining & Marketing in its current state and the 2nd phase is the resulting recommendations part based on the assessment phase.

This is the refinery assessment phase. Its objective is to evaluate and assess the current refining activities in Bangladesh as a study in itself, but also as a basis for the recommendation part of the future setup of the countries refining activities, which is a next step in the study with a separate report.

This assessment will cover refinery technical aspects, economics of the refining activities including the expenses and efficiencies and the logistics surrounding the refinery activities.

Bangladesh has no crude oil production except for small quantities of gas condensates. The overall demand for petroleum products is currently 3.9 million tons per year, mostly diesel and jet fuel and kerosene. The refinery supply is only for 32 % produced by the countries single 1.3 million ton product output /year refinery that has been in operation since 1968, Eastern Refinery Ltd (ERL) located in Chittagong. Another source of products but on a very limited scale, less than 1%, is made available by Petrobangla's gas processing facilities located at the Northern Bangladesh gasfields in the district of Sylhet.

As a consequence of the limited capacity of the refinery, 68% of the country petroleum product demand is imported from other refineries in the Middle East and Asia. The purchase of the imported petroleum products and the for the refinery required crude oil is carried out by Bangladesh Petroleum Corporation, a state owned company.

There are private oil companies that are contributing to the overall supply, but these companies are only allowed at present to trade in LPG, Bitumen and Lubricant oil and some fuel oil for their own consumption and not in the mainstream products like gasoline, kero and diesel to the end consumers. As a result the product supply from private companies is less than 7% of total demand.

Another aspect of the Bangladesh demand is the very high proportion of distillates; Diesel, and Kerosines which make up for 86% of all petroleum products demand.

If the ERL refinery capacity could be simply enlarged by a factor 3 to meet the total current country demand even then it would be impossible to produce this kind of product yield despite use of other type of (distillate rich) crude oils and/or major investment in deep conversion facilities are made.

With a growing demand Bangladesh will have to increase its imports further and as a result will increase the import/local supply imbalance as ERL is already at maximum realistic capacity. The demand will also likely change in yield with products such as heavy fuel oil becoming more important with the Government recent emphasis on increased power generation.

Compared with the world wide refinery configurations ERL at a rated capacity of only 33.000 barrel per day is a ‘ small sized ’ relatively simple refinery complex, with very limited flexibility to increase the quantity and quality of the petroleum product output. Also the Vacuum Unit, Hydrodesulphurisation (in Shutdown) and Catalytic Reformer units are all out of expected proportion in relation to the Crude Distillation Unit.

ERL only conversion unit is the Visbreaker which converts just 16 % of the residual fuel into distillates. The Vacuum Unit is designed for Bitumen production and not to produce higher value vacuum gasoil feedstock for cracking or other applications.

There is no facility to remove unwanted sulphur from distillate products and other key international product specifications cannot be met, such as aromatics and benzene limits in gasoline produced in the South East Asian region.

The Mild Hydrocracker Unit with a dedicated steam reformer Hydrogen unit are not in operation. Both units are shut for some years and will require extensive overhaul to re-instate the facilities to their full service.

ERL is not free to organize the crude oil supplies in the most efficient way for cost and desired moment in time. There are no easy and low cost solutions to solve the low draft problem of only 9.15 meters. The shallow coastline will not permit anywhere in Bangladesh to receive a direct crude oil vessel discharge. Although the Karnafulli river at Chittagong is one of the deepest draft ports in Bangladesh there is still the requirement to lighter the crude oil vessel at anchoring points 70 km from Chittagong. ERL relies therefore on small lightering vessels. Lightering is a complex and expensive procedure and is organized by the Bangladesh Shipping Corporation.

This procedure not only causes delays and extra risks but also increases the transportation costs by 1.50 usd/barrel (11 usd/ton) compared to a sufficiently deep draft port that could take Aframax and Suezmax vessels.

BPC and ERL will have to consider the few possible solutions such as using larger shuttle tankers and higher pumping speeds or possible a costly investment in a new Single Point Mooring facility to be installed in deep draft waters outside Kutubdia Island with a pumping station and a crude oil /products pipeline connection to Chittagong.

ERL has more than sufficient storage facilities to receive the lightered vessel shipments of Arabian light and Murban crude oil and the current volumes of imported petroleum products. All ERL storage tanks are very close to the vessel mooring and load/discharge facilities and the three large marketing company product terminals which receive the refined products for redistribution throughout the countries depot system. The ERL plus marketing companies combined overall storage tank capacity for products is almost 600.000 ton, enough to accommodate a much larger refinery operation than today's ERL refined product output plus imports.

ERL total operating cost per barrel is 1.21 USD/barrel. This compares favorably with many refineries because the number of staff is relative low and overall personnel cost, usually the largest cost component in a refinery, is just 17%. However depreciation is relative high and reflects the investment in the Secondary Process Complex in 1994. Repair and maintenance is a relatively low cost component with just 0.15 USD/barrel taking the high ERL process unit age and current excellent state of the refinery complex into account. Also not all advantages of larger refineries typical economics of scale are applicable to the small refining capacity complex at ERL and this will limit the efforts to save on operating expenses.

On of the most relevant refinery costs is the energy consumed by the refining process. Efficiency assessment proves that the ERL refinery is well placed compared to standard refining operations and ERL burner fuel consumption as a yield percentage of own fuel consumption around 2.3 % of intake is what can be expected. Very efficient, in particular is the performance of the ERL Visbreaker unit, one of the largest burner fuel consumers.

ERL generates its own electricity and steam. The power and process steam generation is conventional technology and resultant efficiencies of only 30-35% are realistic. Improvement can be made here with investment in high efficiency (65-75%) Combined Heat and Power systems. The utility complex uses purchased gas for its burner fuel consumption which is a relative low cost in ERL expense, however the purchase costs are only 30% of world gas prices and therefore not reflecting true energy consumption costs.

ERL serves its parent BPC as a service organization where BPC pays a processing fee for each refined barrel of crude oil, plus a product improvement incentive devised on import/export parity price of the concerned products. For 2007-08, ERL's total fee income per barrel of crude oil processed was Tk. 110/barrel and with total ERL expenses of Tk. 83 per barrel, the year was positive and ERL made a profit. It needs to be noted that the product improvement incentive is largely dependent on import/export parity price, and is not an assured income. As such, operating on a low to modest processing fee, ERL operations may run the risk of being unsustainable.

However, a fee/cost analysis will not be a fair indication for the overall refining margin potential. For that a different approach will give more insight on the question, if the current refining operation will remain sustainable in the longer run.

For that a different approach will give more insight on the question if the current refining operation will be sustainable in the longer run. Most refineries are benchmarked on this ability and a similar approach is done for ERL. In this analysis ERL product output revenue is valued at international benchmark price (Platt's Fob Singapore) for the respective products less true delivered cost of purchased crude oil and less the refining expenses (including losses and own consumption). This analysis should reveal at least some potential to judge on investments and basic strength and sustainability of the refining operation.

The outcome is that for ERL the results over the last 3 years have been a break even to just negative (0.54 USD/barrel) operation with positive margins in 2008 followed by negative margins for 2009 and 2010 (data till August).

Although the observation period is relative short, just 32 months, the results are quite volatile. This typically reflect international Oil Markets where market circumstances and thus petroleum product and crude oil prices will vary from month to month. In particular the years 2009 and 2010 are worldwide characterised with depressed consumer demand and therefore lower product prices.

However this refining margin strength analysis should not be the only decision point to build and operate refineries, but should guide decisions on investment in enlargement and conversion units and in improved efficiencies and variations in crude oil type feedstock slate.

Dependency on foreign imports is another aspect of the current situation and the cost of over 68% of total demand being product purchases.

ERL refining operation is also important to assist in the processing of the locally produced Natural Gas Condensates (NGC) from Petrobangla and others natural gas fields. Currently the NGC production represents 20% of the ERL crude oil slate and ERL is, with approx 200.000-250.000 ton/year condensate supply, close or already at its maximum ability to process all NGC. Any increase will seriously limit the crude processing volumes. Petrobangla's Kailastilla plants 1 and 2 have some excess capacity left but need reliable power electricity supply which is not there now according to Petrobangla.

Bangladesh has to accommodate and capable to handle its only self produced source of petroleum feedstock and this will require adequate processing facilities.

ERL currently buys on long term purchase agreements Arab Light and Murban crude oil. Prices paid are competitive and the supply contracts are stable and guarantee a good security of supply. But both are relative expensive crude oils compared to other candidate crude oils and refiners margins may be improved by close examination of other lower cost crude oils that would suit the ERL refinery configuration. However this may require a whole different supply route with other possible aspects that need further examination. Major oil companies and other trading organisations with refining assets make these margin optimisations their business, but such approach to the international markets will require a different view on the domestic security of supply.

Main observations and conclusions:

1. ERL refinery is a small refinery of very simple configuration.
2. At current demand level, ERL can meet only one-third of petroleum product's demand of the country, it's contribution, though will shrink further with the increased demand, nevertheless, it acts as a proven fall back system and provides reasonable energy security.
3. Except the Visbreaker Unit and Bitumen blowing Unit (past of Asphaltic Bitumen Plant) other process units are undersized in proportion to the crude Distillation Unit (CDU). Visbreaker Unit and Vacuum Unit has spare capacity.
4. ERL has adequate and comfortable storage capacity for crude oil and products. considering the tank ages of the nearby main installations of the three marketing companies, available whenever necessary. ERL can sustain the operations of a much larger refinery.
5. Electricity generation capability of ERL cannot be considered comfortable and reliable. Even to maintain an acceptable on-stream factor for ERL process units, electricity generation capacity need to be improved.
6. Thanks to good preventive maintenance program, despite age, ERL refinery seems be in good operating condition.

Summarised then there is a small and very simple refinery that at best at a break even refiners margin and is just able to meet one third of current Bangladesh petroleum product demand which is expected to grow fast in the very near future. All facilities are well maintained for its age and level of technology but ERL capacity expansion is without major investments in the current refinery and transportation configuration not realistic.

CHAPTER 1: ERL ASSESSMENT OF CURRENT OPERATIONS

1. INTRODUCTION

Any petroleum refinery is a production facility composed of a group of refining process units to convert raw material like crude oil and other hydrocarbon based feedstocks into finished oil products of value to individual and industrial consumers. The Bangladesh Petroleum Corporation (BPC) under the Energy & Mineral Resources Division of the Ministry of Power, Energy & Mineral Resources (PE&MR) owns Eastern Refinery Limited, a company with the only refinery complex in Bangladesh and other logistic facilities in Chittagong.

Eastern Refinery Limited, a full subsidiary of Bangladesh Petroleum Corporation was incorporated as a Public Limited Company in 1963 with 35% EPIDC (East Pakistan Industrial Development Corporation) shares, 30% shares held by Burmah Oil Company (BOC) and the rest 35% by private entrepreneurs. From November, 1985, Bangladesh Petroleum Corporation (BPC) became the 100% share holder of the company.

The capital structure of ERL is an authorized capital of 5000 million Taka in 500 million ordinary shares of 100 Taka each. Paid up capital is 330 nillion Taka. (ERL annual report 2008-09)

ERL owns the only Petroleum Refining Complex of Bangladesh, installed on a picturesque expanse of 190 acres on the bank of river Karnaphuli.

ERL refinery went on stream with crude processing capacity of 1.5 million ton per year from May 8, 1968. ERL also owns and operates a Dolphin Oil Jetty RM-7 (mainly for imported crude oil reception) 4 Kilometers of crude oil reception lines and 10 Kilometers of product export pipelines.

ERL, now has 5 processing units; the Crude Distillation Unit, Catalytic Reforming Unit, Asphaltic Bitumen Unit, Long Residue Visbreaker Unit & Mild Hydrocracking Unit. It produces 15 petroleum products including 4 non fuel products, of which the most important are MS-Regular(Petrol) , MS-Premium (Octane) , Kerosene, Diesel, JBO, Bitumen etc.

ERL plays a vital role in supplying around 33% of the country's current petroleum product demand.

This section will address a summarized description of the main features of ERL in relation to its applied main technology used, the refineries operating costs, output performance and service as central point in Bangladesh petroleum product supply. Detailed description, and a due diligence of process units and fact finding for each major unit at ERL, with remarks and comments, the supply to and from the refinery with logistics and economics are described in detail in separate chapters.

2. ASSESSMENT OF USED TECHNOLOGIES OF MAIN UNITS

2.1. General description

ERL refinery is located at the entry of the Karnaphully river. The chosen refinery location Chittagong is the deepest draft port in Bangladesh. Nevertheless Bangladesh is seriously disadvantaged because the shallow draft which is in Chittagong is only 9.15 meters at high tide and does not permit uninterrupted and efficient transportation of crude oil and oil products.

The refinery was built in 1966-1967. Technip and IPF did the design and engineering. Production started in 1968.

This means that the core of the refinery has been in operation, except for maintenance shutdown, for over 40 years, and although ERL units are all,(after superficial inspection) in excellent shape due to scheduled routine and preventive maintenance, the basis technology is now outdated and less efficient with regards to furnace efficiency and other heat transfer in exchangers, reboilers and strippers than compared with today's new build refining installations.

- Crude oil distillation unit (CDU) 33000 barrel/day in operation since 1968
- Catalytic Reformer unit(CRU) 1700 barrel/day in operation since 1968
- Hydrodesulphurisation unit (HDS) 1800 barrel/day converted in 1994 into a Mild Hydrocracker; now mothballed
- acuum distillation unit (VDU) 4000 barrel/day in operation since 1980
- Bitumen Blower 70.000 ton/year in operation since 1980
- Long Resid Visbreaker Unit(VBU) 10500 barrel/day in operation since 1994
- Hydrogen Steam Reformer 790 ton/year shutdown
- Merox units
  - Kero 125000 ton/year in operation since 1968
  - Naphtha 100000 ton/year in operation since 1968
  - LPG 25000 ton/year in operation since 1985
- Utilities(power+steam) 8 MWh in operation
- Storage facilities(gross) 571000 cbm in operation since 1968

2.2. Highlights and key assessment points

Basis the above configuration some qualitative assessment remarks can be made about ERL refinery:

- ERL is a ' small sized ' refinery complex, with relative limited flexibilities to considerably increase the quantity and quality of the petroleum product output. Note that the average worldwide refinery size expressed in crude oil distillation capacity is 162.000 barrel/day, compared to ERL 33.000 barrel/day.
- The Vacuum Unit, Hydrodesulphurisation (in Shutdown) and Catalytic Reformer are all out of expected proportion in relation to the CDU distillation yield for intermediate product flow and their logical design size based on the CDU fractions.
- ERL does not have significant cracking or major residue conversion units and is a relative simple refinery.
- ERL only conversion unit is the Long Residue Visbreaker which contributes per 100% barrel crude approx 7% Fuel oil into Distillates. Feedstock is CDU Atmos Resid instead of, like in most refineries Vacuum Resid, due to the very small capacity sized Vacuum Unit, designed for Bitumen production and not to prepare feedstock for cracking.
- There is no facility to remove sulphur from distillate products and key international product specifications in the region cannot be met.
- Not all ERL's units are in operation and may require extensive overhaul to reinstate to full service.
- There is ample storage facilities for crude oil and petroleum products given the daily refinery throughput and close vicinity of the offtake facilities and logistics.
- Utilities are based on conventional design and reliability may be less than required to safeguard the operation.

2.3. Benchmarking ERL with other refineries using the Nelson complexity index

Refineries worldwide are compared and benchmarked according certain procedures, like Solomon, and Nelson indices.

It is far from easy to compare refineries as so many different factors not only technical, but also, political, geographical, and economical aspects have an impact on a refinery configuration. Nevertheless ERL should be compared to a few typical refining installations to support some of the observations made above.

The **Nelson complexity index** was developed by Wilbur L. Nelson and published in a series of articles in Oil & Gas Journal . The term describes a measure of the secondary conversion capacity of a petroleum refinery relative to the primary distillation capacity.

The Nelson complexity index assigns a complexity factor to each major piece of refinery equipment based on its complexity and cost in comparison to crude distillation, which is assigned a complexity factor of 1.0. The complexity of each piece of refinery unit equipment is then calculated by multiplying its complexity factor by its throughput ratio as a percentage of crude distillation capacity. Adding up the complexity values assigned to each unit, including crude distillation, determines a refinery's complexity on the Nelson Complexity Index.

Nelson's Complexity Index (NCI)

The NCI is then a measure of the conversion capacity of a refinery. It is therefore a broad measure of the refinery's ability to upgrade residual fuel oil to higher value products.

The Index for a refinery is calculated by multiplying the complexity factor (see table below) for each unit by the ratio of its capacity relative to the atmospheric distillation capacity. The results of the calculations are then added to arrive at the refinery's NCI.

The following are the complexity factors for some standard processing units:

Atmospheric Distillation	1
Vacuum Distillation	2
Thermal Cracking/Visbr	2.75
Coking	6
Catalytic Cracking	6
Catalytic Reforming	5
Catalytic Hydrocracking	6
Catalytic Hydrorefining	3
Catalytic Hydrotreating	2
Alkylation	10
Aromatics / Isomerisation	15

As a simple example, a refinery with a 100.000 barrel/day atmospheric distillation unit and a 50.000 barrel/day catalytic cracking unit would have an NCI of 4. The sum is then1 for the distillation unit plus 3 (50/ 100 * 6) for the cracker.

The Nelson complexity index indicates not only the investment intensity or cost index of the refinery but also its potential value addition. Thus, the higher the index number, the greater the cost of the refinery and the higher the value of its products.

The total group of USA refineries as an average rank highest in complexity index, averaging 9.5, compared with Europe's refining system at 6.5. But the Jamnagar refinery belonging to India-based Reliance Industries Limited is now one of the most complex refineries in the world with a Nelson complexity index of 11.3 .

Essentially a high Nelson Complexity Index, like the Reliance Jamnagar Refinery, usually points to the following characteristics:

- Ability to process inferior quality crudes or heavy sour crudes. For example the Jamnagar Refinery generally processes high sulphur above 3% sulphur crudes of 10-20 API which are at least 5 API lower and 0.7 wt% higher sulphur compared to other Indian and Japanese and Singapore peers.
- Ability to have a superior refinery product slate comprising of high percentage of LPG, Gasolines, light distillates and middle distillates and low percentage of heavy products such as fuel oil. For example the Jamnagar Refinery produces no fuel oil except to use in its own process unit furnaces.
- Ability to make high quality refinery products such as export grade US and Euro type gasoline and/or diesel and high quality feedstocks for the petrochemical industry.

Outcome of the benchmark for ERL is summarised in the table below:

Unit at Refinery		ERL	HALDEA	Reliance Jamnagar	Pertamina Balikpapan	ESSO Baton rouge	BP Rotterdam
	Nelson Complexity factor (NCI)	Rated capacity 000bbl/day in % CDU	Rated capacity 000bbl/day in % CDU	Rated capacity 000bbl/day in % CDU	Rated capacity 000bbl/day in % CDU	Rated capacity 000bbl/day in % CDU	Rated capacity 000bbl/day in % CDU
Atmospheric Distillation	1	33 100%	61 100%	588 100%	241 100%	503 100%	392 100%
Vacuum Distillation	2	4 12.1%	27 44.3%	380 64.6%	89 36.9%	232 46.1%	86 21.9%
Thermal	2.75	10.5 31.8%	9.6 15.7%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Coking	6	0 0.0%	0 0.0%	125 21.3%	0 0,0%	114 22.7%	59 15.1%
Catalytic Cracking	6	0 0.0%	0 0.0%	130 22.1%	0 0,0%	229 45.5%	115 29.3%
Catalytic Reforming	5	1.7 5.2%	5.3 8.7%	120 20.4%	19 7.9%	76 15.1%	30 7.7%
Catalytic Hydrocracking	7	0 0.0%	0 0.0%	120 20.4%	50 20.7%	27 5.4%	0 0.0%
Catalytic Hydrorefining	3	0 0.0%	0 0.0%	0 0.0%	0 0.0%	70 13.9%	0 0.0%
Catalytic Hydrotreating	2	0 0.0%	5.3 8.7%	186 31.6%	0 0.0%	383 76.1%	348 88.8%
Alkylation/MTBE	10	0 0.0%	0 0.0%	24 4.1%	0 0.0%	39 7.8%	9 2.3%
Aromatics/Isom	15	0 0.0%	0 0.0%	85 14.5%	10 4.1%	10 2.0%	0 0.0%
Asphalt	1.5	1.2 3.6%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Lub	10	0 0.0%	0 0.0%	34 5.8%	0 0.0%	16 3.2%	0 0.0%

Hydrogen	5	0	0.0%	0	0.0%	19	3.2%	0	0.0%	22 4.4%	0	0.0%
NCI Factor			2.4		2.9		11.3		4.2	10.7		6.5

From the simple NCI ranking in this table there are very large differences in outcome.

Note that a low NCI represents a simple low cost and limited refinery, a high NCI is assigned if the refinery operates deep conversion facilities, and can make the products that are conform the strictest specifications for sulphur, aromats and benzenes.

Conclusion is that ERL has a low NCI compared to most European, US and Asian refineries. However there are refineries in the region that have similar values, although all of these have a much larger Crude Distillation capacity, to which the NCI does only assign a value of 1. Size of refineries are not measured in this NCI calculation. But remains the mere fact that Esso Baton Rouge and Reliance Jamnagar belong to the largest refineries and thus have an enormous product output potential which serves economics of scale, and of course demand satisfaction in that region. For that same reason Pertamina's refinery scores relatively low at 4.2, although it possesses a large (low sulphur) crude distillation capacity operation with a resid hydrocracker.

The relative quantities of petroleum products produced by a refinery (its "product slate") depend thus on the complexity of the refinery processes, the market demand and the properties of the crude being processed. The complexity is related to the many operating units that are used to separate the crude into fractions, improve their quality and increase the production of higher-valued products like gasoline, jet fuel, diesel oil and home heating oil. These processes range from the relatively simple crude oil distillation to the more complex ones: vacuum distillation, catalytic reforming, catalytic cracking, alkylation, isomerization and hydrotreating. In general, refineries can be classified as **hydroskimming, cracking** and **deep conversion,** in order of both increasing complexity and cost.

The most complex, deep conversion refineries are able to transform a wide variety of crudes, including the lower quality heavy sour crudes into the higher value products (e.g., gasoline, diesel). The ability to meet stringent product specifications, notably ultra low sulfur gasoline and diesel fuel, is also a characteristic of high complexity refineries. Historically, the very complex refineries have been most often located in the United States, where gasolines are in greatest demand. Highly complex refineries, however, are not restricted to the U.S. They are becoming more common in Europe and Asia.

ERL by comparison is a relative modestly configured refinery and has a very limited overall Crude Distillation processing capacity and capability to meet regional product specifications. It would be classified between hydroskimming and cracking refinery type.

In the following table shows a summarised yield comparison on the basis of identical crude oil intake between ERL (10 year average yield) and one European and US refinery , both refineries were also used in the Nelson comparison above

Refinery yield performance

Output	ERL %wt	BP Rotterdam %wt	Esso Baton Rouge %wt
LPG	1.0%	3.5%	0.4%
Naphtha	11.4%	15.2%	2.5%
Gasoline	6.6%	17.0%	44.3%
Kero/Jet	22.1%	25.2%	23.1%
Diesel, Gasoils	29.2%	19.2%	25.6%
Fuel Oil	23.9%	7.5%	1.2%
Bitum/lubric	3.6%	8.0%	0.0%
Cons/Loss	2.2%	4.5%	3.0%
	100.0%	100.0%	100.0%
Intake			
Murban	43.6	43.6	43.6
Arab Light	47.9	47.9	47.9
Condensate	8.5	8.5	8.5
	100.0%	100.0%	100.0%

Capacity (in CDU barrel/day)	33.000	392.000	503.000
Refinery Type:	Hydroskimming	Cracking	Deep Conversion

There is a striking difference in output performance. However it should be realised that there is a very large amount invested to reach these yields in the BP and Esso complex refining configurations.

It simply means that depreciation of these investments are a part of the Operating expenses and higher than for ERL. Also the refineries own fuel/gas consumption and process losses is much higher than for ERL. Against these higher costs are a much higher revenue as a result of the higher conversion quality and corresponding better yield performance compared with those of ERL.

3. ASSESSMENT OF QUALITY OF THE YIELD AND MODE OF OPERATION

As in above table the capacities of all other ERL units beside the CDU expressed as a percentage of the CDU are low. It is normal to expect the downstream units to reflect the volumes of the CDU fractions, like approx 50 % Vacuum Unit capacity and 10-15 % Reformer unit capacity and at least 30 % Hydrodesulphurisation.

This is not the case at ERL and contributes to the very broad Distillate oriented yield compared to more balanced outputs of gasoline, jet fuel and kerosene, gasoil/diesel, heavy and vacuum gasoil and fuel oil given the crude oil slate.

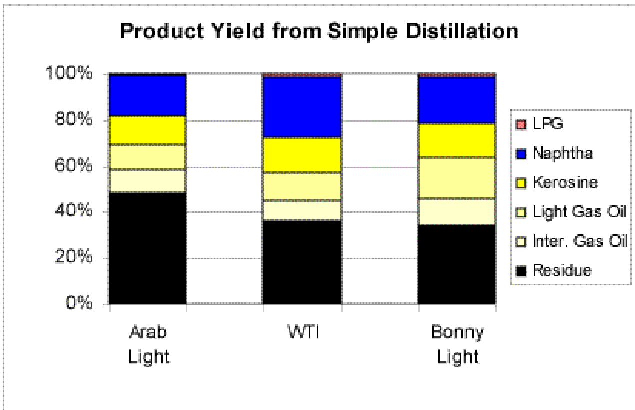
The ERL CDU is designed for light to medium heavy crude oils, in the range 40 to 25 API. The CDU pre flash column and the main fractionators are most likely designed with Arabian light crude as the main crude oil slate. Although the crude oil unit received a thorough revamp the basis rundown structure is essentially unaffected.

ERL in recent years has been processing increased quantities of Natural Gas Condensates that will have an impact on the distribution of low distillation fractions through the main Crude Oil Fractionator.

Currently the Condensate is processed in the distillation section of the Mild Hydrocracking unit and thereby leaves the Main CDU fractionator well relieved from very low boiling Naphtha and Kero fractions.

One of the most important factors that determine the product yield is the choice of crude oils in the feedstock slate. ERL for many years has been running on Murban and Arab light crude and some local produced Nat Gas Condensates. A different crude oil slate produces a different yield, as presented in the simple distillation comparison below.

Naturally each crude oil has its own characteristics, and its own costs associated with how the international markets perceive the value of that crude oil, its transportation costs, and other. A lighter low sulphur crude may not be the best crude from a refiners margin optimal point of view as costs differ but so does the value and yield of the refined products.



Source: Energy Intelligence Group, *Int'l Crude Oil Market Handbook*

The following table shows the expected ERL yield compared to the actual realised yield (2008).

The expected yield information for Arab light and Murban is taken from Crude Assays (Shell) and the Nat Gas Condensate from a Petrobangla simplified assay. Visbreaker yields are based on test data in respected literature (see also chapter ERL Visbreaker)

		Simple Material balance ERL basis 2008 data			

	Arab lt	Murban	Condensate		Visbreaker	ERL	ERL	Difference
	CDU yield	CDU yield	CDU yield	Average	conversion	expected	actual	actual-expect
product	**% wt**	**% wt**	**% wt**	**% wt**	**effect**	**yield**	**yield**	**yield**
losses/cons	2.1	2.3	2.0	2.2		**2.2**	**2.0**	**-0.2**
Residue/bitumen	42.8	34.0		33.7	-5.7	**28.0**	**27.5**	**-0.5**
Diesel+JBO	20.3	26.6	10.0	21.6	5.7	**27.3**	**29.2**	**1.9**
Kero	9.7	11.3	17.0	11.3		**11.3**	**22.0**	**10.7**
Naphtha+ MS	23.6	25.0	70.0	30.1		**30.1**	**18.5**	**-11.6**
LPG	1.5	0.8	1.0	1.1		**1.1**	**0.8**	**-0.3**
	100.0	100.0	100.0	100.0		**100.0**	**100.0**	**0.0**
Crude		**Ton**	**%**					
Murban		521694	41.2%					
Nat Gas Cond		162654	12.9%					
Arab light		580990	45.9%					
Total		1265338	**100.0%**					

3.1. Observation and remarks:

The yield analysis outcome is a pleasant confirmation of the good quality of ERL's refining operation in general:

- Given the refinery configuration ERL manages to approach almost exactly the actual amount of Fuel Oil produced compared to expected. Since Fuel Oil is the lowest valued product it simply means that ERL gains almost the maximum possible outcome in value.
- ERL mode of operation is to maximise Kero and minimise Naphtha. This is explained by the demand in Bangladesh for Kero and also the optimisation of the relative value difference between Kero and Naphtha.
- ERL's own consumption and losses are in line with expectation and means that there arte no major inefficiencies incurred.

Note:

1. The overall energy use efficiency in this table is just the processing units fuel and gas consumption. Total energy use is also dependent of purchased fuels and Natural Gas for use in the ERL Utilities and in some ERL furnaces and this will add to the total energy use. The issue will be described in more detail in the economic assessment sections.
2. The quality of the products and whether specifications are met is not addressed in this analysis. Kerosine with very low flashpoints, Gasolines with less than standard Octane rating and high sulphur Diesel etc are here classified as such without benchmark with regional specifications.

4. ASSESSMENT OF THE OPERATING EXPENSES

Petroleum refining is a capital-intensive business. A grassroots refinery of average complexity processing 100.000 barrels crude per day may cost a billion dollars to build.

For a refinery to be economically viable, its operating cost must be under strict control and the goal is to minimize direct operating expenses . Refineries are built and operated with these objectives in view. Large throughput refineries can be built with initial investment costs spread and depreciated over the course of many years but depreciation is usually a major yearly cost outside the refinery direct control. Many operating cost elements, such as depreciation, insurance, and in many countries personnel, cost remain constant with refinery throughput. These indirect operating cost per barrel crude processed is minimized by using the maximum allowable capacity of each unit. This chapter discusses the direct operating costs of the refinery (allocation of operating costs) as its goes on doing its daily refining business

A refinery operating cost can be classified under the following heads:

- Personnel cost. This includes salaries and wages of regular employees, employee benefits, pension contributions, contract outside maintenance labor, and other contracted services.
- Maintenance cost. This includes maintenance materials, contract maintenance labor, spare parts and equipment rental.
- Insurance. Insurance is needed for the fixed assets of the refinery and its hydrocarbon inventory.
- Depreciation. Depreciation must be assessed on refinery assets: plant machinery, storage tanks, marine terminal, and the like.
- Chemicals and additives. These are the chemical compounds used in processing petroleum and final blending, such as antioxidants, antistatic additives and anti-icing agents, pour point depressants, anticorrosion agents, dyes, water treatment chemicals, and so forth.
- Catalysts. Proprietary catalysts in Platformer, Hydrodesulphuriser, etc.
- Rent/Leases to be paid. Fees for Land, Port charges, buildings, also unit licences fees etc.
- Daily consumables. Purchases of Fuel Oils and Gas for burning or feedstock(Hydrogen plant) use, purchased water and electricity.

General and administrative costs. This includes all office and other administrative expenses. These costs are NOT taken into account here as they have no immediate bearing on the refinery performance.

Operating expenses are difficult to obtain as refining organizations do not publish these nor is there a good reference to the actual underlying operation. ERL has operated since 1999 to 2008 on average 330 days per year. This includes all shutdowns, planned and unforeseen. Other refineries may have lost many more days and may show very high maintenance due to age or bad accidents, fire, flood etc.

Interesting nevertheless is to compare the major expenses like personnel, maintenance and purchased utilities.

4.1. Observation and Remarks:

- ERL total operating cost per barrel is 1.21 USD/barrel. This will compare favourably with many refineries.
- The number of staff is low and overall personnel cost, usually the largest cost component, is just 17%.
- ERL depreciation is relative high and reflects the investment in the Secondary Process Complex in 1994.
- Repair and maintenance is relative low with just 0.15 USD/barrel taking the ERL process unit age and current excellent state of the refinery complex into account.
- The Purchased Gas as a furnace fuel is undervalued. At 5.84 Taka local price per Ncbm it is approx. 30% of current world gas prices. If revalued at international market levels the cost of gaspurchase is 0.56 USD/barrel and 35 % of total Operating expense (Opex). This is high and efficiencies in modern Utility units like Combined Heat Power will bring this cost in line with others

ERL's operating cost data are from the 2007-2008 Annual report.

	ERL			BP Rotterdam			PetroKazakhstan Shymkent		
throughput	crude tons	1213800			15,492,561			4,280,000	
	feedstock	0			5,336,159				
location type		sea/coastal			sea/coastal			inland	
supply/offtake		vessel			vessel/pipe			pipe/rail	
configuration		simple			very complex			medium complex	
	usd/mln	usd/bbl	%	mln usd	usd/bbl	%	mln usd	usd/bbl	
salaries/wages	1.8	0.21	17.0%	60.1	0.39	16.5%	6.2	0.20	44.0%
other employee cost	1.2	0.13	10.8%	32.4	0.21	8.9%	0.0	0.00	0.0%
chemicals	0.3	0.03	2.6%	15.8	0.10	4.3%	0.3	0.01	2.1%
repair/maintenance	0.2	0.03	2.2%	36.9	0.24	10.1%	1.1	0.03	7.8%
spare parts	1.0	0.12	9.6%	0.0	0.00	10.1%	1.2	0.04	8.5%
fuel,power/water	0.5	0.05	4.4%	53.1	0.34	14.5%	2.1	0.07	14.9%
gas purchase	1.7	0.19	15.7%	72.5	0.47	19.9%	2.0	0.06	14.2%
insurance	0.3	0.03	2.7%	31.5	0.20	8.6%	0.1	0.00	0.7%
crude oil handling	0.0	0.00	0.2%	13.3	0.09	3.6%	1.0	0.03	7.1%
shutdown	0.1	0.01	0.7%	0.0	0.00	0.0%	0.0	0.00	0.0%
transport	0.3	0.03	2.6%	0.0	0.00	0.0%	0.0	0.00	0.0%
depreciation	3.4	0.38	31.2%	36.8	0.24	10.1%	0.0	0.00	0.0%
other cost (catalyst)	0.0	0.00	0.2%	12.7	0.08	3.5%	0.1	0.00	0.7%
	10.9	1.21	100.0%	365.0	2.37	100.0%	14.1	0.45	100.0%
	taka/bbl	82.86							
	usd/ton	8.96							
number of staff (2008)		626			420			1350	

Overall impression is a normal to low operating cost per barrel refined crude oil for ERL. This is a simple configuration and it cannot be compared to more complex, deep conversion refineries where operating costs are just higher because of the complexity, the use of chemicals and in the case of BP, the maintenance costs.

The only exceptional item at ERL is the cost aspect of the Bakhrabad Gas purchase. If the price that is charged locally for gas is adjusted to reflect a normal international market gas price instead of the current subsidized price, then this would raise the ERL operating expenses from 1.21 USD/barrel to 1.60 USD/barrel.

5. ASSESSMENT OF THE ERL OUTPUT YIELD, IMPORT, AND EXPORTS WITH BANGLADESH DEMAND

This chapter will cover an assessment of the very important issue of imbalances between the current Bangladesh petroleum product demand and the potential supplies from ERL as well as the imported products to meet these imbalances.

As is made clear in above, ERL output is 33000 barrel per day (assumes Arab Light and Murban crude as feedstock to the CDU for 365 days operation) or approx 1.600.000 ton product per year maximum.

Over the past 10 years ERL's CDU has been out of service for routine shutdown activity, on average for 30-35 days, which assumes then a yearly production potential of 335 days with a associated production of 1.490.000 ton/year.

The average yield over the past 10 years gives a good basis for the product output as fluctuations in individual units, irregular shutdown periods, changing crude oil daily runs and general mode of operation changes will be levelled out over such a long period. Also on the crude oil intake side is the introduction over the past few years of increasing quantities of Natural Gas Condensate, which has a considerable effect on the quality of the output; in particular the increase in light Naphtha production.

5.1. The demand and supply

The 2009-2010 financial year demand for petroleum products, controlled by BPC is 3.882.000 ton with ERL only able to supply (average 10 year output) 1240.000 tons. This leaves at least 2.640.000 tons of product or 68% uncovered from own refining resources and has to be imported from other refineries outside Bangladesh.

Bangladesh thereby is highly dependent on imported oil to meet the demand of various petroleum products in the country.

This aspect of the ERL role for the energy supply should be assessed with questions like:

- Is it acceptable that the petroleum product demand is so dependent on imports.
- Is the demand better served with exclusively refined products from ERL or any Bangladesh based refinery either State owned or private enterprise owned and operated.
- Is the import of crude oil, the refinery supply guaranteed and long term protected by market forces or other in the long term.
- Should the petroleum product supply be driven by economics only.

- Is the demand based on true market prices or is there potential demand distortion by Governments subsidizing product prices.

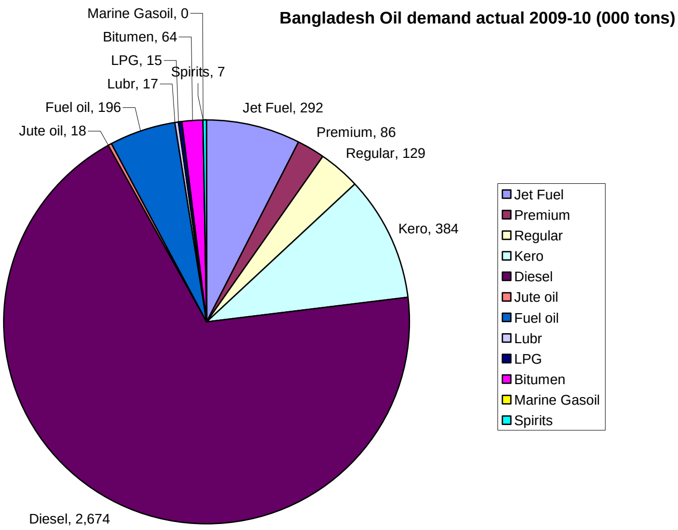
These questions will not be answered in this assessment but are at the core of the recommendations with regard to the Bangladesh Petroleum products refinery capacity expansion.

The liquid fuel market that necessitates the import of crude oil and finished products will also grow with economic development. Future product demand projections and the possible scenarios will be discussed in the Marketing part of the study.

For now this will put further pressure on Bangladesh to import besides crude oil sufficient petroleum products to keep up with petroleum product demand at a time when crude oil prices seem to have consolidated above US$ 70 per barrel, and may yet rise to higher levels as global economic recovery ensues. The importation bill for crude oil is of the order of US$ 600 million per annum, and for the additional product import US$ 1,600 million. Bangladesh Petroleum Corporation (BPC) imports the additional finished petroleum products to meet market demand. Other, relative small imports are done by the private sector only for LPG, Bitumen and Lubricants, as the private sector is restricted to trade these products only, as per government policy.

Bangladesh Petroleum product sales actual 2009-2010

(Source BPC) :



The demand distribution graph shows Diesel oil to be by far; nearly 2700 Mton, the single largest demanded product. Besides the diesel other major demands are for the Jet A1 aviation fuel, about 290 Mton, and the household kerosene 384 Mton.

As the demand for all these products increases, ERL's market share is gradually decreasing to less than 32 % today.

Bangladesh supply and demand

~~000 Ton~~

000 ton	Actual Demand 2009-10 BPC		ERL output avg 10 y		import/export volumes 2009-2010	Import as% of demand %
Jet Fuel	292		[illegible]		-289	~~-99%~~
Premium	86		37		-49	~~-57%~~
Regular	129		75		-54	~~-42%~~
Kero	384		295		-89	~~-23%~~
Diesel	2,674		346		-2,328	~~-87%~~
Jute oil	18		17		-1	~~-6%~~
Fuel oil	196		308		112	~~57%~~
Lubr	17		[illegible]		-17	~~-100%~~
LPG	15		13		-2	~~-13%~~
Bitumen	64		52		-12	~~-19%~~
Marine Gasoil	[illegible]		[illegible]		[illegible]	
Spirits	[illegible]		[illegible]		[illegible]	~~2%~~
Naphtha			84		84	
~~TOTAL~~	~~3,882~~	~~100%~~	~~1,240~~	~~32%~~	~~2,642~~	~~68%~~

5.2. Imports

The gap between ERL output and overall demand does as such not have to be the reason for adjusting the output potential. Many countries depend on international markets for their product supply and petroleum markets for crude oil and products are the largest and most actively traded. Participation in petroleum trading just requires some basic elements, such as:

- availability of storage facilities and redistribution logistics to handle products. Bangladesh has a wide distribution infrastructure with Chittagong the centre of the petroleum handling of imports.
- Commercial sound contacts in that international market with a variety of suppliers.
- The ability to finance the purchase of these imports. The total import costs bill currently is approx 2.3 Billion USD per year. It is understood that BPC and ERL have strong and good relationships with local banks.

Imports of Diesel, Jet Fuel, Kero and High Octane (95RON) are coordinated by the BPC commercial trading division.

Most contracts are for the duration of 6 months to 1 year with various suppliers in the AG and Singapore region. BPC buys on a CIF and C&F Chittagong basis for the product import.

Contract prices are in line with international market practices:

- Diesel ex AG refinery priced at Platts AG Gasoil 0.25% sulphur plus a premium of 3.80 - 4.00 USD/barrel. Quantity per year; approx 2.3 million ton or almost 100 vessels (of 25 Kt size) per year.

- Jet Fuel ex AG, Platts AG Kerosine plus a premium of 4.40 USD/barrel. Quantity per year approx 300.000 tons or approx 12 shipments per year.
- High Octane Gasoline at Platts Ron 95 unleaded plus a premium of 7.50 USD/barrel. Quantity approc 100.000 tons or 4 shipments per year.

The basic contracts pricing formula is the average Platts of the 5 quotations around the Bill of Lading day. Payments are usually 30 days after Bill of Lading date.

All these contracts seem reasonable as the premium negotiated also covers the transportation to Chittagong and some insurance. Also market circumstances may change with a consequence for the premium at the time of negotiation of the contracts. The economics chapter provides further analysis on the matter of imports.

5.3. Exports

The only current exports is the ERL produced surplus product Light Naphtha. This fraction remains as there is no use in Bangladesh. Light Naphtha is traditional feedstock for the petrochemical industry where it is cracked and converted into products like polyethylene, polypropylene, styrene, etc, building blocks for products like rubbers and plastics.

ERL produces small quantities of approx 100.000 tons per year and sells this on a FOB Chittagong basis usually via a mini tender system in batches of 20-25000 ton.

Buyers are offering Platts Singapore quotations less a discount of 2-3 USD/barrel to cover the cost of transportation.

This price is at market levels as ERL's light Naphtha production is very light and otherwise of reasonable quality.

In the past ERL occasionally had surplus Fuel Oil which was exported and sold on basis of similar procedures, but with growing demand for Fuel oil exports have stopped and likely there is now a substantial deficit expected in the near future.

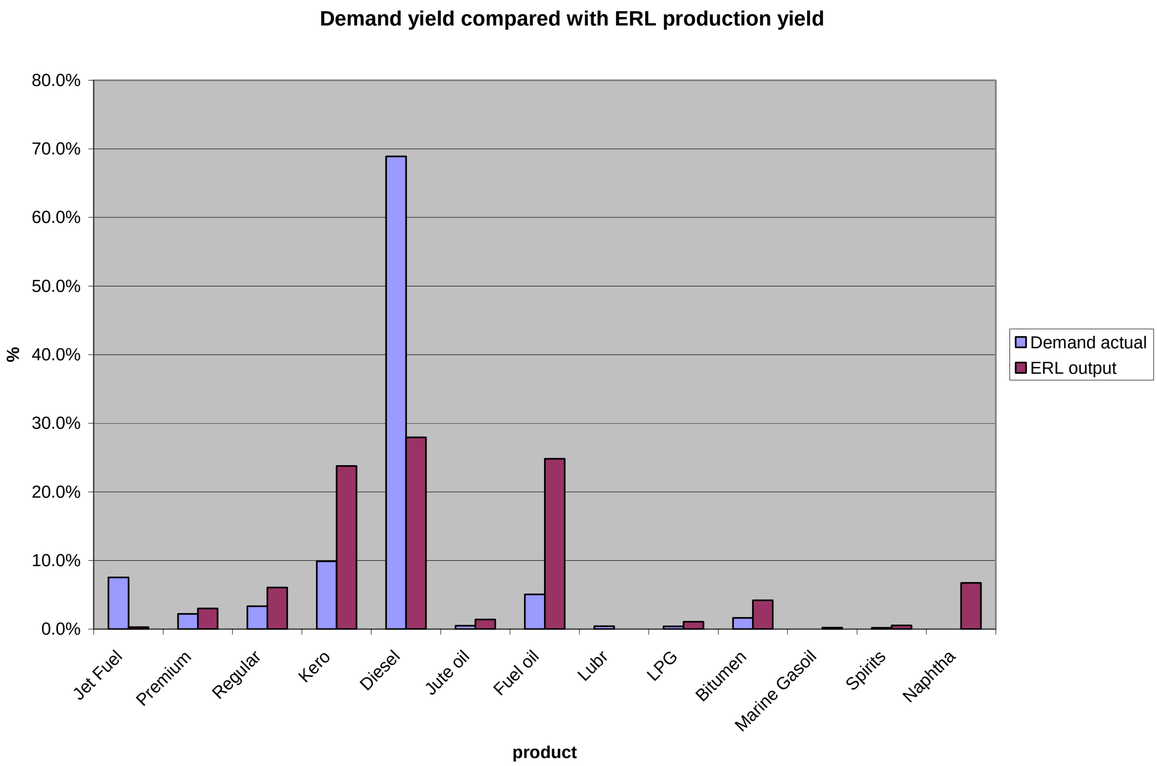
5.4. The demand pattern and ERL yields

The other important aspect of the ERL output compared with demand is the product quality differences of demanded and by ERL produced and supplied product slate. Here the main import products Diesel and Kerosine are at some imbalance between ERL current configuration's 'natural' yield on crude oil and the very much distillate driven petroleum demand. The mode of operation is maximised toward the production of Kero and Diesel and in that process other natural production like light Naphtha is minimised.

This will become even more unbalanced with expected demand growth in these products for the next 10 years.

The quality of demand versus yield is made clear in the flowing graph:

Note that this graph shows a percentage of each product in either the demand or the output yield.



The graphics and the table below merely illustrate that the demand is entirely concentrated in Distillate, Diesel and Kerosine (incl Jet fuel), while production is more evenly spread according to the crude oil natural yield while still maximized for maximum distillate production.

The refinery even if enlarged to meet the total demand, cannot produce in the same product volumes as is demanded, or al least not with the current crude oil feedstock basis and the refinery configuration.

In other words; if ERL could in its current configuration be enlarged from a 1240.000 ton/year output capacity, to a bigger refinery with capacities equal to total demand of 3882.000 ton/year, then some products would still be in deficit, while others are in surplus. The following table illustrates this principle:

Note: In this table ERL is **artificially resized** by a factor 3882/ 1240 (= 3.1) equal to Total Demand in tons/year.

ERL yield enlarged to meet total demand

000 ton	Demand actual 2009-2010	%	ERL output avg 10 y	%		ERL capacity equal demand	Surplus/ Deficit
Jet Fuel	292	7.5%	3.3	0.3%		10.3	-281.95
Premium	86	2.2%	37.1	3.0%		116.2	30.26
Regular	129	3.3%	75.3	6.1%		235.8	106.43
Kero	384	9.9%	295.0	23.8%		923.6	539.96
Diesel	2,674	68.9%	346.3	27.9%		1,084.3	-1,590.09
Jute oil	18	0.5%	17.4	1.4%		54.5	36.04
Fuel oil	196	5.1%	307.9	24.8%		964.0	767.71
Lubr	17	0.4%	0.0	0.0%		0.0	-16.52
LPG	15	0.4%	13.0	1.0%		40.7	25.68
Bitumen	64	1.6%	51.8	4.2%		162.2	98.45
Marine Gasoil	0	0.0%	2.5	0.2%		7.8	7.55
Spirits	7	0.2%	6.7	0.5%		21.0	14.40
Naphtha			83.7	6.8%		262.1	262.06
TOTAL	3,882.4	100.0%	1,240.0	100.0%		3,882.4	0.00

Therefore, if ERL could be enlarged in all unit capacities by 3.1 times its current operational capacity, then there would still be quite large importation required for Jet Fuel and Diesel, while there would be relative large surpluses for Gasolines, Kerosine SKO and Fuel Oil.

5.5. ERL resize to match total product demand; part of recommendations

The point of this assessment is that simple enlargement of the existing operation would not be a good match for meeting the Bangladesh demand because of the gross inequality of demand yield and refinery yield. Therefore if enlargement in this methodology would be realistic the solution in the above tables inequalities would be to trade surpluses for deficits.

Perhaps future demand in some products may rise, such as the Fuel Oil requirements for Power Generation Plants using heavy fuel oil as burner fuel.

Also ERL may well consider to change its configuration and processing methods to become able to produce Jet A1 Fuel. This kind of kerosene output yield change via operational adjustment of refinery parameters eliminates some of these surpluses in this (hypothetical) presentation of refinery supply.

The issues raised and the outcome of the quantitative and the qualitative performance of ERL with regards to future petroleum products demand expectation is going to be at the centre of the recommendations part of the study. For now this is the assessment that ERL in its current configuration is suffering from a low capacity for all its units, and also has a low complexity in upgrading Residuals to Distillates.

6. ASSESSMENT OF ERL CURRENT CONFIGURATIONS REPLACEMENT VALUE

With all observations and comments about ERL process units, there is a monetary value that can be assigned to the refinery

There are two approaches :

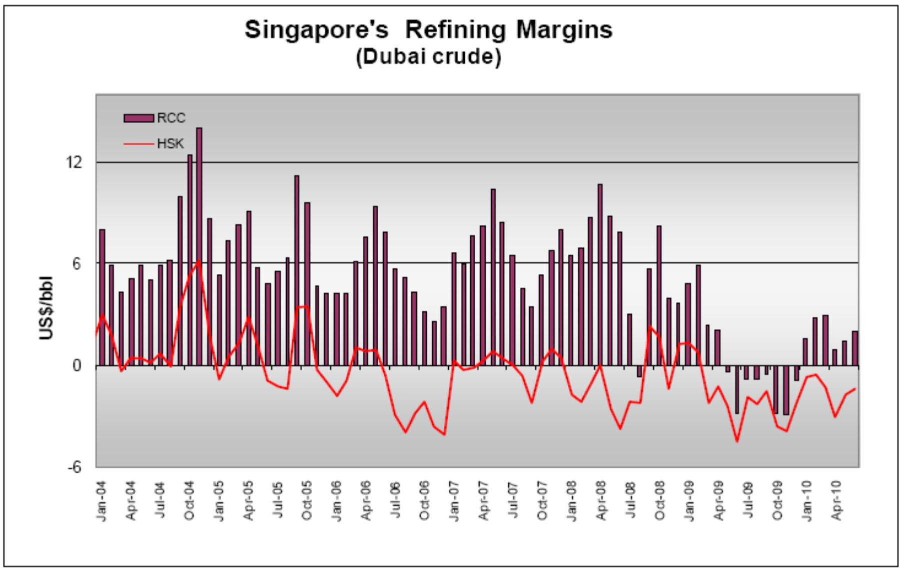
1. Valuation of the ERL assets as if considering buying the future profit potential is valuing the equity of the refinery by looking solely at its cash flow. This approach is the most common in Free Market Economies where assets provide future income, which form the basis for current value of the investment. Once the asset is build its theoretical intrinsic value becomes zero and it's the earning capacity that counts from that moment on.

   If ERL at an 33000 barrel daily run would generate over its expected lifetime of assume 30 years a net refiners margin (after all operating expenses except depreciation) of 1.00 USD/barrel then the theoretical value for ERL would be 185 million USD based on all future earnings.

   This is the Net Present Value method and assumes a cost of invested capital, (= interest in free market economies) of 5% in this example. The theoretical ERL value is the discounted value of all yearly cashflows. Of course margins in the international free market environment are far from fixed but vary on weekly basis.

   However an expectation of a 1.00 USD/barrel may not in the long run be an unrealistic average value as is visible in the generic graph below . See also chapter XX on economic assessment of ERL performance.

Refining Margins, Product Cracks and Prices



Note:

In the graph the red continuous line represents a typical hydroskimming refinery margin, the bar graph is the more complex refinery configuration margin

- all non process unit assets like the marketing terminals, product loading jetties, pipelines etc are not included in above number, as these are part of the distribution network with its own value.
- The NPV calculation here assumes a new investment. ERL of course is an existing facility and its lifetime of 30 years may only be realistic if units are replaced or thoroughly revamped at the end of their technical life.
- Also Bangladesh will have a different approach to investment and cost of capital and this method may not be fully understandable and good for every day use.

The second approach:

2. The second approach is the valuation based on actual replacement construction costs. It assumes the prices of steel, engineering and unit design, construction etc. There is however no simple price list for refinery units as each differs in design, capacity, location and quality of construction. The actual replacement cost approach can therefore only be an approximation.

A general adopted method is to value units in a generic way, based on input from recent actual construction outcome and indexation for costs of materials, labour, etc.

This methodology is developed and maintained by J. Gary and G. Handwerk in their well known book; Petroleum Refining Technology and Economics. Oil and Gas Journal uses the method for its valuations and was recently updated in April 2007. As such the authors claim that the method is suitable for approximating the economics and investment of various refining configurations, but not sufficiently accurate for definitive comparisons of unit processes.

For ERL current configuration the replacement value today following the indexation method would be in the region of 176 million USD.

REFINERY UNIT CAPITAL COSTS

From OGJ 23 Apr, 2007

		Cap '000 bpsd	Cap cost $ mill
CDU	incl desalter	33.0	58.5
VDU+ asphalt		4.0	19.8
Reformer		1.7	19.6
Visbreaker		10.5	39.7
HTU	naphtha	1.7	7.9
HTU	Distillates	1.8	14.5
H2 mmscfd	Steam methane	1.0	4.0
Sulphur	merox recovery	5.0	6.6
Utility MWh	power+steam	8.0	4.9
			175.6

Of course it is an indication only, and preferably is verified by engineering and design specialists.

Observations and remarks:

- An investment of 176 million USD with an assumed 30 year technological end of life period would depreciate yearly by 5.9 million USD and the depreciation charge is per barrel throughput 0.49 USD/barrel. Currently ERL allocates 0.38 USD/barrel actual 2007-2008 to depreciation.
- Replacement would never be exactly the same construction as technological innovations and design improvements are applicable to a current refinery construction project, with better performance in yield, efficiency and lower cost.
- The indexation method does not entirely cover the construction economics of scale advantages. A 33000 barrel refinery is very small, but the cost of installation of pumps, pipelines, tanks, strippers, reboilers are almost the same as would be for a bigger refinery.

7. ASSESSMENT OF ERL AND MARKETING COMPANIES STORAGE AND LOADING/UNLOADING FACILITIES

Chittagong is the central location in Bangladesh for the petroleum downstream sector activities. It has for any of the existing natural harbours in the country the deepest possible draft (9.15 meters) and is the basis for the only refinery; ERL. Despite this the refinery output is only able to meet 32% of the total current country demand of 3.9 mliion tons per year. The remainder 68% of petroleum products is imported with 25.000- 30.000 ton vessels that can just enter the harbour draft without lightering.

All these activities require storage tanks and jetties, pipeline connections , loading racks and inland waterway barges, railcar facilities etc. Chittagong is the centre because all these basic requirements for a country wide supply program are concentrated in the Patenga area, Chittagong.

8. ERL REFINERY STORAGE FACILITIES

The type of tanks and storage volume required depends on a multitude of dependents like

8.1. Feedstock tanks; crude, condensates, other feeds like atmos resids. This is the supply side to the refinery and volume required depends on:

8.1.1. Drop size of the supplying vessel.

For ERL this dimension is set by the limitations of Chittagong port and Kutubdia anchoring points maximum draft. Supply takes place with small Suezmax and Aframax class vessels and on average is 130.000 CBM (110.000 ton) per delivery.

8.1.2. Daily run rate of the refinery.

For ERL in its current operation; close to maximum capacity of 33000 barrels/day, this is equivalent to 5250 CBM (4500 Mton) feedstocks per day.

8.1.3. Number of different feedstocks (and separate run rate) to be kept segregated

ERL uses 3 different crudes currently and wants to keep these segregated for reasons of rundown requirements. Arab light is a for bitumen feed qualified crude while Murban is not. Nat Gas Condensate does not meet normal crude oil characteristics and needs for this reason its own separate storage treatment. If then drop size for each crude oil vessel supply is 130.000 CBM and the refinery maintains discharge with full segregation and not using its tank bottoms, ERL would need 260.000 CBM of storage.

This is the most conservative approach. As both crudes; Arab Light and Murban are drawn down, new crude oil supplies would be expected to be stored in ERL empty tanks on top of bottoms as crude oil bottoms are not really impacting operations.

On average the draw on both crudes would go in runs of a few days, therefore on average 130.000 CBM would be in tank for both crudes together.

8.1.4. Minimum required (compulsory) stocks

This volume requirement is normally set by the government, but would naturally be covered by existing stocks of crude oil and products. If 30 days is to be used for compulsory stocks then ERL would have to keep 157000 CBM in tank, and may be as crude or as products, or as a combination of both.

8.1.5 Average minimum supply days between the next drop, sailing time

The journey time from loading terminal in the AG to Kutubdia anchoring would be 11 to 12 days at 12 Knotts speed and in normal weather conditions. To be included are the days for the first lightered crude shipments into Chittagong. A total of 15-18 days to bridge the supply time from load to in ERL tank, multiplied by 5250 cbm crude runs per day is just under 100.000 CBM crude.

8.1.4. Normal operating buffer stocks

ERL operations would not want to be forced into a shutdown without observing normal operating procedures. An unforeseen and unpredictable event, such as storms, strikes, etc should require a minimum buffer stock should the supply sequence be interrupted. Most refineries maintain at least one week of crude oil supply as minimum buffer. For ERL this would be 40.000 cbm crude in tank.

None of the above considerations will be limiting for ERL.

Current net total crude feedstock storage (excluding tank bottoms) is 263.000 cbm net, and gross, incl bottoms of 302.000 CBM for the storage of Arab Light, Murban and NatGas Condensates.

ERL tanks will allow to store crude oil for approx 50 current capacity run days, which is far more than would be required, even with above consideration 1.3 . A very preliminary assessment of the operation would suggest that the storage is sufficient to feed a 100.000 barrel day refinery, basis a target stock sufficient to stay for 16 days in operation. Such target is coinciding with the required resupply days of approx 16 days for sailing from AG to Kutubdia plus some lightering days. None of the other considerations under 1. would neither cause a violation of this suggestion.

ERL Tank allocation	*type*	st tanks	gross capacity cbm		net capacity cbm	ERL output yield	ERL output approx cbm daily rundown	year import	days capacit	turns per year
Crude		7	278000		241072	91.5%	4750		51	
Gas Condensate		4	24500		22294	8.5%	500		45	
		11	**302500**	**87%**	**263366**		**5250**		**50**	
LPG	**finished**	**2**	2200		2050	1.0%	52		39	
Naphtha	**export**	**6**	43200		38361	6.8%	357		108	
Light Na comp	**interm.**	**2**	2500		2386	0.6%	31		76	
HOBC	**interm.**	**1**	2000		1645	2.8%	147		11	
Gasoline comp	**interm.**	**3**	4400		3928	4.3%	226		17	
Gasoline	**finished**	**1**	2000		1645	5.9%	310		5	
Import Gasoline	**import**	**1**	13000		12491			80000		6
S Kero	**finished**	**3**	6000		5728	23.0%	1207		5	
Kero JP1	**finished**	**1**	2000		1909	0.3%	16		121	
Diesel	**finished**	**4**	18278		17529	27.2%	1427		12	
Diesel import	**import**	**2**	63000		56411			2000000		32
Jute oil	**finished**	**1**	2000		1909	1.4%	73		26	
LVacGO	**interm.**	**1**	1300		1244	2.0%	105		12	
HVacGO	**interm.**	**2**	2600		2487	3.0%	157		16	
MHC feed	**interm.**	**2**	1000		950	1.0%	52		18	
RCO Atmos Resid	**interm.**	**5**	65000		62563	33.0%	1731		36	
Fuel Oil	**finished**	**5**	33570		32118	24.0%	1259		26	
Bitumen	**finished**	**5**	2500		2378	4.1%	215		11	
water		**1**	2000		1909					
		48	**268548**	**93%**	**249641**		**5145**		**49**	

Following the feedstock side of the storage the next part will look at the refined product side.

8.2. Refined Products; finished and intermediate (rundown) products.

The combined ERL refinery product storage and the Marketing Companies storage facilities have to be seen together to form an opinion about the overall capabilities for refined product flexibility and daily required storage. Although the three marketing companies each have their own sales business and loading racks for local trucks and rail cars, by far the majority of the products are delivered to small tankers for further distribution into depots. ERL feeds the adjacent marketing facilities on a continuous basis from its own product storage and therefore the total available product storage is relevant, irregardless of ownership.

For BPC, who owns both ERL as well as more than 50% of the Marketing Company assets, there should just be no discrimination to utilize the combined storage to its best optimal situation without limiting the individual sales activities of the three marketing organisations. In such a setup ERL would have one larger tank farm for its products to be stored and delivered to the main distribution channels.

First there will be an analysis and assessment of the ERL storage facilities for finished products and rundown/ intermediate products.

The type of tanks and storage volume required depends as was with the crude oil storage on a multitude of dependents like:

8.3. Number of different finished products

ERL currently produces 14 different products that all require to be stored separate and in different type of tanks (fixed roof/floating roof). There are also requirements to store the large quantities of purchased imported finished products like Diesel and Jet Fuel. Since Bangladesh consumption is 3.8 million ton per year, with the refinery producing only 1.3 million tons, means that the service provided by ERL to handle imported products is almost twice as large as the refinery output itself. Such an unusual operation is only possible with sufficient number of tanks and the required volume of storage capacity. The advantage of imported products is that ERL can benefit from the imported product quality and blend its own finished and/or intermediate product with the imported product to either improve to the required specification or to upgrade intermediate product into finished product. Blending margins of 2-5 USD/ton in particular for Gasoline and Diesel are not uncommon. This is certainly the case where high octane gasoline is blended with ERL's own lower octane components like Naphtha and low RON Platformate. Also some of the heavier gasoil streams can be upgraded to Diesel by using the often lower gravity and higher cetane of the import. All these operations require tanks and throughput capacity.

Part of ERL tanks are also dedicated for Export from Bangladesh to international customers via the Jetty 7 and 6. This is mainly Light Naphtha and small volumes of Fuel Oil.

ERL produced main finished products are Diesel, Kerosine, Jet Fuel, Gasolines, Naphtha and Fuel Oils. On average for the main products, there is storage capacity to allow a refinery production for 10-15 days. This should be more than sufficient as the main off take from the refinery tanks is via a dedicated pipeline system to the nearby marketing installation of Jamuna, Meghna and Padma companies.

8.4. Required intermediate product volume and dedicated storage tanks

ERL is a relative simple refinery configuration which produces its most important finished products like Diesel and Kero (SKO) direct from the units. There is hardly any intermediate tankage required unless some of the imported Kero and Diesel is blended with the ERL production for optimization of quality and for economic benefits. Gasoline will require intermediate storage as it is a blend of 3 to 5 different components. Volumes are relatively modest due to the small capacity of the Platformer.

The main intermediate tank volume is required for the Atmospheric Residual Oil (RCO) from the Crude Unit. This is an intermediate stream that will be further processed in the Vacuum Unit and in the Visbreaker. Daily output of RCO is approx. 2000 CBM/day and it would be good refinery practice to use a buffer to the equivalent of 10 days, or 20.000 cbm. ERL has allocated 65000 CBM to the RCO and is thereby more than sufficient covered to deal with this intermediate product. ERL could handle 3 times as much output of RCO, without compromising its operation. This is equivalent to 100.000 barrel per day crude throughput..

8.5. Daily run rate of the refinery and import of products

The majority of Products imported are mainly Diesel, Kero and Jet Fuel. ERL has dedicated 63000 cbm to the largest import; Diesel. Since vessel size is 30.000 cbm this volume is more than sufficient to accommodate the discharge. Turnover of that import tank is high; 32 times per year which is equivalent to a re fill of the diesel tanks every approx. 11 days.

The refinery Diesel production itself has sufficient storage to accommodate 12 days production.

For both, import and production, Diesel operations have thereby more than sufficient storage to operate.

For the Kero(SKO) there is 5 days accomodation for ERL produced SKO. This is a tight situation and should be reviewed and possibly arrange to add an additional tank allowing 10 days of storage. Although the Kero volumes are less ERL may create some flexibility in case the marketing company SKO offtake is interrupted.

8.6. Lifting of products; frequency and mode of lifting

ERL has itself no influence or is involved in the decision on the offtake frequency, except for the export of Light Naphtha. The Marketing Companies determine their program and in good cooperation with ERL the products are pumped from the refinery to the nearby marketing storage facilities. However with the demand for petroleum products increasing every year, there will only be more frequent offtakes than was in the past. For products storage it should therefore be a Marketing companies and ERL joint product storage exercise, as discussed earlier.

8.7. Required minimum (compulsory) stocks

ERL and the Marketing companies both have more than sufficient storage capacity in Chittagong to meet a 30 day country demand. With 3.8 million ton/year demand which is equivalent to 12000 CBM per day, ERL with its 250.000 cbm nett product storage capacity can hold up to 21 days of product, while the marketing companies together operate in Chittagong with 325.000 cbm net or 27 days of product storage.

8.8. Normal operating product stocks

Normal buffer stocks to facilitate an uninterrupted flow though tanks should be no more than 5 days for the smaller volume products like Gasoline and 7 days for Diesel, Fuel oil and Kero. This is normal practice in most refining centers. In ERL case there is the additional advantage of the nearby Marketing Companies storage facilities.

A special case is the LPG storage.

Liquified Petroleum Gas storage is different from petroleum liquids as the facilities will have to store and pressurize the LPG to around 7 kg/cm2. These tanks are expensive to build and are usually critical in there volumetric design. ERL has 2200 cbm storage which is large compared to its daily rundown production.

In general the available storage for ERL 's refinery operation, including the handling of import of Diesel , Jet Fuel and KERO should give no limitation for the current operation and for the main products the ERL facilities could handle. The assessment is that the current storage facilities can handle a much larger volume of crude oil and products than currently is done.

9. QUALITY OF THE STORAGE FACILITIES

ERL maintenance does allocate sufficient money and time to keep the tanks in very good condition. Most of the tanks were first built together with the ERL processing facilities in 1967. Although only a superficial examination took place, the tanks and connecting lines and manifolds were all in very good condition, freshly painted, properly repaired, all with clear indications for the right product contents, safety codes and tank sizes. Where visual examination was possible there appeared no signs of major leaks due to less integrity of the tank horizontal and vertical plating. Some oil was found into the bunded area and in the nearby gulleys and streams, but this was the result of tank and pipeline cleaning and only of minor concern. All tanks are connected to a central monitoring system with software from the auto tank gauging system from Motherwell with on line information about movement, volumes, densities, low and high level alarms.

This sophisticated system is operated from the Oil Movement office inside the tank farm.

Since most liquids can spill, evaporate, or seep through , special consideration must be made for their safe and secure handling. This involves the building of a bunding, or containment dike, around the tankfarm area, so that any leakage may be safely contained. ERL bunds looked well maintained and without gaps.

Some storage tanks have a floating roof in addition to or in lieu of the fixed roof and structure. This floating roof rises and falls with the liquid level inside the tank, thereby decreasing the vapor space above the liquid level. In particular in Bangladesh with temperatures all year around 35 degrees storage losses of petroleum is critical and floating roofs are considered a safety requirement as well as a pollution prevention measure for volatile petroleum products.

Tanks for a particular fluid are chosen according to the flash-point of that substance. At ERL (and the Marketing Companies) , there are fixed roof tanks, and floating roof tanks.

1. Fixed roof tanks are meant for liquids with relatively high flashpoints, (e.g. heavy vacuum gasoil, fuel oil, bitumen etc.) ERL has sufficient domed roofs tanks and some are insulated to prevent the clogging of certain materials in particular Bitumen and high viscosity Fuel Oil, wherein the heat is provided by steam coils within the tanks.
2. Floating roof tanks are broadly divided into external floating roof tanks (usually called as floating roof tanks: FR Tanks) and internal floating roof types (IFR Tanks).
3. Spheres. ERL has 2 identical spherical tanks each 1100 CBM for LPG.

IFR tanks are used for liquids with low flash-points (e.g. Jet A1 aviation Fuel, MS, Gasoline components, Naphtha, Solvents etc.). These tanks are cone roof tanks with a floating roof inside which travels up and down along with the liquid level. The floating roof traps the vapor from low flash-point fuels. Floating roofs are supported with legs on which they rest. For ERL all of the tanks used for Gasoline, Naphtha and crude oil are IFR.

FR tanks do not have a fixed roof and have a floating roof with proper seal only. Medium flash point products such as, diesel, and other distillates as well as crude oil etc. are stored in these tanks.

The 2 LPG spheres are capable to store 2200 CBM and will accept pressure well up to 20 kg/cm2 . This pressure holding capability is necessary to hold LPG as liquified product from the normal high vapour pressures of Propane and Butane gasses at atmospheric conditions. Both spheres are filled up with LPG, which then finds it way to the nearby LPG bottling facility which is located within a few 100 meters from the spheres and adjacent/on the refinery site.

All tanks are attached to pipelines connecting ERL with the jetties, LPG gas bottling plant and the three marketing companies storage facilities nearby.

LPG storage is different from other product storage because of its high vapour pressure. Often the volume of LPG storage facilities is the first to limit the refinery operation. In ERL case there is a daily production of approx 30 tons per day (equivalent to approx 55 liquid cubic meters) The availability of 2200 cbm storage , effectively set at 2000 CBM effective utilization, would mean storage capacity of well over one full month of LPG production, which is quite unique and offers a good basis to expand production or increase the volume from imported LPG. Normal storage volume for gasses at most refineries is less than 15 days production. For ERL there is constant and very reliable offtake from the bottling plant adjacent to the LPG spheres operated by LP Gas. The plant is under utilized and could process 21000 ton LPG/year instead of the currently 13-15000 tons production from ERL.

10. MARKETING COMPANIES CHITTAGONG TANK TERMINALS

As explained in the introduction, adjacent to ERL refinery site are the storage tanks of the marketing companies : Padma Oil Company Ltd (POCL), Jamuna Oil Company Ltd (JOCL) and Meghna Petroleum Ltd (MPL) to a total of approx 325000 CBM capacity for all products, except LPG. See the table below:

Combined Marketing Companies Chittagong Tank allocation

	capacity ton	cap cbm	throughput year 08-09 cbm	sales yield	tank turnovers per year	days capacity equiv
HOBC	9549	12648	88132	2.5%	7	52
Gasoline MS	16760	22199	130672	3.7%	6	62
S Kero	47286	59108	371679	10.5%	6	58
Kero JP1	24213	30266	324733	9.2%	11	34
Diesel	117052	138523	2432651	68.5%	18	21
LS Diesel	1680	2012	2370	0.1%	1	310
Jute oil	4713	5386	16824	0.5%	3	117
LDO	1810	2011	63	0.0%	0	11652
SBP	194	259	1262	0.0%	5	75
MTT	1804	2313	6552	0.2%	3	129
Fuel Oil	36673	38603	169373	4.8%	4	83
Luboil	10220	11169	4456	0.1%	0	915
	271954	324497	3548767	100.0%	11	33

The total throughput for all marketing companies is just under 3.6 mln ton in the year 2008-2009. Which implies that on (all product) average the tanks are filled and emptied 11 times per year or almost one full in out operation per month.

For Diesel this is higher; 18 times per year, because of the imports. Part of the imported Diesel is received in ERL tanks and after blending with ERL produced Diesel, dispatched to the Marketing Companies Terminals. Given the emphasis on the Diesel demand this should not be a problem with the routine offtake scheduling.

For an average terminal 11 times throughput per year is low and should be a very easy operation, unless there are major events that causes the supply and offtake to stop altogether like fire, flooding, strikes, earthquakes etc.

With ERL’s own net product storage of approx 250.000 cbm there is then a total of 575.000 CBM of net product storage capacity. These combined tank farms will serve a throughput currently 3.9 million ton of product, of which 32 % is delivered from ERL refined products output and 68% from finished product imports delivered by vessels to the jetties 6, 7 to the refinery tanks and marketing companies storage tanks for blending..

This means that operated as one total (ERL+ Marketing) tank farm of 525 000 cbm the facility is more than sufficient to be used as main product storage and throughput, where each average storage tank is used only 6.7 times per year to handle all current in Bangladesh demanded petroleum product streams. Such a large tankfarm should be able to handle with ease more than double and could likely handle even three times the current 3.9 million tons year volume if required, to a total of 12 million tons per year without difficulty. Of course the capacity depends as explained on a variety of factors, but product supply is instantaneous and there are no unusual offtake hurdles at Chittagong for the delivery of refined products.

Padma, Jamuna and Meghna Companies each use approx 20 % of their throughput in the Chittagong facilities for their local area sales via truck and rail, and therefore 80 % of the total throughput is leaving the Chittagong terminals with coastal and river barges to inland depots throughout Bangladesh. This means that these terminals handle (together with ERL facilities) almost all (99%) of the total demanded volume of petroleum products.

Each terminal has its own jetty for loading of coastal tankers and if required to accommodate seagoing vessels for imports of Diesel, Kerosine and Gasolines. Meghna (MPL) and Padma (POCL) each have a similar jetty as ERL crude jetty 6, well capable to handle all volumes.

Although the pumping capacity is relatively low ; less than 1500 cbm per hour, there is no limitation caused in the efficiency of the product distribution. Jamuna (JOCL) operates a pontoon jetty which is much smaller than the fixed and more robust jetties at POCL, MPL and ERL. Pumping capacity at the JOCL jetty is less than 150 ton/hour and therefore only loads the smaller tankers.

ERL, LPGL and the three marketing companies receive, process and market petroleum products from Petrobangla companies e.g. Sylhet Gas Field Ltd. (SGFL), Rashidpur Gas Field, Rupantarito Praketic Gas Ltd. (RPGL). LPGL receives LPG at its Kailashtila LPG bottling plant. ERL receives natural gas condensate shipped from Ashuganj terminal. POCL, JOCL & MPL receives low octane gasoline & low flash, low cetane diesel from Petrobangla's NGL fractionator plants. Distillate products are not on-specification. NGL is processed at ERL as crude mix and also partly in the now dedicated fractionator of the MHC Plant.

This Petrobangla supply is less than 1 % of the Bangladesh total product supply, and therefore not a major factor for the overall supply of products.

11. QUALITY OF THE MARKETING COMPANIES STORAGE FACILITIES

Similar to the situation at ERL, the majority of the marketing company's tanks date back to 1968 and even earlier to 1956 for the POCL terminal. Maintenance for all three product terminals is (on a superficial basis) done on a routine basis and the tanks all are in good and even excellent condition, well painted and properly coded.

Some oil was found in the immediate areas around the tanks, and may have been the result of tank cleaning during maintenance. Tanks are routinely rotated for essential maintenance and the terminals are in continuous operation at all times.

POCL has, beside the petroleum products, also a lubricants blending and filling plant with a blending capacity of 25000 ton/per year. It fills drums (159-200 liter) and a variety of cans and bottles. Total storage for base oils is 10220 tons. Drums are locally produced.

POCL also has the use of a well equipped laboratory for basic testing of the imported and blended product qualities.

MPL and JOCL do not blend and process lubricants, but both use dedicated warehouses on their sites to store finished grades lubricant oil delivered respectively from BP and Mobil sources.

12. RELATIVE RANKING FOR CHITTAGONG STORAGE FACILITIES

Although a proper comparison with other storage locations and operations cannot be made, there are some basic principles that can be compared:

- relative number of tank in-out movements per year,

- number of different products and crude handled,
- Total volume through put per year.

The table below compares ERL with a similar located but larger and more complex refinery in Rotterdam and the inland, but similar to ERL configured Shymkent refinery in Kazakhstan.

The last column represents a standard refinery, which represents the characteristics of more than 50% of all worldwide refineries.

000 ton	ERL	BP	Shymkent	Coastal Standard
	Chittagong	Rotterdam	Kazakhstan	100.000 bbl/day
location	Sea, River	Sea	Inland	Sea, River
Year	2008	2008	2005	
Supply	vessel	vessel/pipe	pipe/rail	vessel
Crude imported 000 ton	1240	16247	4280	
Products imported 000Ton	2642	4980		
Other process feedstocks 000 Ton		3320		
Total movement in	3882	24547	4280	5000
Offtake main	vessel/truck	vessel/pipe	rail/truck	vessel, truck
Refined products	3801	22867	4280	
Other exports	84	904		
Total movement out	3885	23771	4280	4800
000 CBM capacity				
Total net crude oil storage	303	2185	195	415
Total Product net storage	268	1986	200	300
Extra storage Marketing Chittagong	324			
Tanks utilised/year				
Crude	4.1	9.0	21.9	12.0
Products	11.0	14.5	21.4	16.0
Products (excl Marketing)	24.0			
number of crudes	3	55	1	10
number of products	14	23	8	12

Some interesting conclusions can be obtained from this overview:

- ERL oil movements are small compared to international standards,
- ERL runs a very few dedicated crude oils and is not setup for typical merchant margin optimization by using many different crudes,
- ERL has ample crude storage, with just 4.1 times per year of full tank turns. Compare with the Shymkent refinery at 22 times, or almost each 14 days from fill to empty,
- ERL has a high products throughput. This reflects the relative high import of products which need to be stored and blended with own production. But combined with all marketing facilities the capacity is more than sufficient,
- ERL has a normal differentiation of product qualities.

This comparison or benchmarking with other refineries confirms that this important Chittagong storage asset is in its current setup large enough to accommodate if required a larger refinery operation without the need to invest in additional tanks.

CHAPTER 2: ASSESSMENT OF ERL TRANSPORTATION COSTS FOR CRUDE OIL AND OIL PRODUCTS

ERL refinery depends for a stable uninterrupted operation like all other refineries on a regular supply of crude oils. However the ease of supply and the facilities to receive (and export) crude oil and oil products varies depending on the local geographic differences and the investments in port facilities. For Bangladesh there are some severe draft and other infrastructure restrictions that will have an impact on the actual crude oil storage facilities and the costs of crude oil supplies to ERL Refinery.

The ERL refinery location at the mouth of the Karnafulli river limits the refinery to accommodate its shipping requirements for incoming crude oil and oil product supplies and outgoing product sales. Chittagong Port Authority advises for port entry a maximum allowable draft (at high tide) of 9.15 meters and along Jetties No2 to No13 a maximum draft (at high tide) of 8.55 meters. ERL has one crude oil Jetty, No7 and can use if required Jetty No 6 for discharge of crude oil into its storage tanks which are approx 1.9 km from the shore.. The 3 marketing companies each operate their own jetties for import of petroleum products, and for the redistribution of the oil products to their across Bangladesh located terminals.

ERL jetty RM7 (and RM6) characteristics:

1. mooring and (un)loading of a single vessel at the time with 4 loading arms. (2 for crude and 2 for products).
2. pumping to ERL tanks via a 18 inch with 20 inch header mainline to shore at 1400 cbm/hour via 2 loading arms. (original design speed 2000 cbm/hour)
3. Concrete/steel permanently fixed T shaped pier.

1. CRUDE OIL IMPORT

Crude oil supplies from the Middle East, Africa, and Far East will for economic and all kinds of practical reasons use vessels with deadweight ton capacities from 80.000 (Aframax) to 140.000 tons (Suezmax). These vessels have a fully loaded draft of at least 13 to 17 meters resp and cannot as such discharge direct at the ERL jetty.

ERL for all its years in operation relies on a lightering operation due to the draft limitations. Current crude supplies are from Abu Dhabi terminal Jebel Dhana and from Saudi Arabia Ras Tanura. The voyage to Chittagong will take around 12 days under normal weather conditions.

The mother vessel usually anchors at a location point south approximately 80 Km of Chittagong (21degr 41 min North Latitude, and 91 degr 40 min East Longitude)

This anchoring area near Kutubdia Island has a water depth of 16 meters, just enough to support the loaded draft of (smaller) Suezmax class vessels.

All chartering and, in ERL case the specific situation of draft restriction, the provision of special arrangements for crude oil vessel transportation is carried out by The Bangladesh Shipping Corporation (BSC). The Bangladesh Shipping Corporation is a state owned and managed public sector Corporation. It is the largest ship owner in Bangladesh and was established on 5th February 1972.

BSC provides crude oil transport and lightening services to Bangladesh Petroleum Corporation (BPC) for carrying crude oil from the mother vessels anchored at Kutubdia outer anchorage to Eastern Refinery Limited (ERL) shore tank as their lighterage contractor with the two purpose built lighter vessels M.T. Banglar Jyoti and M.T. Banglar Shourabh, each 14540 Dead Weight Ton. BSC runs their operation on a commercial basis with time and spot charters. Lightering is the ship-to-ship offshore transfer of crude oil from larger vessels such as ULCCs, VLCCs or Suez- and Aframaxes to smaller tankers that are capable of entering shallow-draft ports Crude oil lightering is a complex offshore operation dependent on effective scheduling, specialized equipment and expert ship handling. The lightering process consists of maneuvering a smaller tanker (service vessel) alongside the larger tanker to be lightered, typically with both vessels underway. The two vessels are moored together with lines while using large rubber bumpers called fenders between the two vessels to prevent damage. A portion of the crude oil cargo from the larger ship is discharged through hoses connected between the two vessels to the smaller ship. The two vessels may be anchored or may continue underway while the transfer takes place depending upon sea conditions.

Lightering is an environmentally dangerous operation and spills are likely to occur if the whole operation takes place underway.

In ERL's case the larger tanker will be lightered for its entire cargo by the smaller vessels as draft of even a partially loaded Crude oil vessel may not be sufficient to enter Chittagong port. Also the cost of keeping the mothervessel will incur further demurrage that may be more expensive than using extra lightering vessels.

The pricing of crude oil transportation services occurs in a highly competitive global tanker charter market. A broker is usually involved in the deal and acts as an intermediary between the vessels owner and the charterer. The major hubs of shipping are located in New York, London, Oslo, Singapore and Tokyo.

One of the key aspects of any charter party is the freight rate, or the price specified for carriage of cargo. The freight rate of a tanker charter party is specified in one of four ways: by a lump sum rate, by rate per ton, by a time charter equivalent rate, or by Worldscale rate. In a lump sum rate arrangement, a fixed price is negotiated for the delivery of a specified cargo over a period in time, and the ship's owner/operator is responsible to pay for all port costs and other voyage expenses. Rate per ton arrangements are used mostly in chemical tanker chartering, and differ from lump sum rates in that port costs and voyage expenses are generally paid by the charterer. Time charter arrangements specify a daily rate, and port costs and voyage expenses are also generally paid by the charterer.

Worldscale rates (WS), the most common freight rate arrangement for oil tankers relies on a yearly assessed freight scale cost (by the Worldscale Asociation in London) in USD/ton for each possible voyage between 2 or more ports. This cost number reflects a cost per ton which would cover the fixed and variable costs of the vessel, port charges and other specific costs for a route. Charterer and owner negotiate then a rate or percentage off the fixed rate as the for that voyage agreed price. Current rate for Suezmax (130.000 ton) on one the most popular route in the Mediterranian is around 100%. Other common shipping routes are West Africa-USA and Arab Gulf- Singapore, with very similar WS rates.

1.1. Tanker Vessel classes:

Aframax vessels are tankers with a deadweight between 75,000 and 119,999 tonnes. Aframaxes tend to carry dirty cargoes, most often in parcel sizes of 70,000 or 80,000 tonnes (500,000 to 700,000 barrels). Typical routes include Caribbean exports to the US Gulf, lightering movements in the US Gulf, North African exports to Southern Europe, North Sea and Baltic exports to Northern Europe and South East Asian exports to the Far East.

Panamax vessels are tankers with a deadweight between 50,000 and 74,999 tonnes. Originally named as a result of being the largest vessels able to transit the Panama Canal, panamaxes can carry clean or dirty cargoes, depending on the vessel or trade route. They transport, for example, Arabian Gulf exports to Asia and product trade between North Europe and the Mediterranean.

Suezmax vessels are tankers of deadweight between 120,000 and 199,999 tonnes. Originally named through being the largest vessels able to transit the Suez Canal, Suezmaxes mostly carry dirty cargoes, especially crude oil, in parcel sizes of 130,000 tonnes (around one million barrels). Typical routes include West African exports to the US and Europe, North Sea exports to the US and Europe and some Arabian Gulf exports.

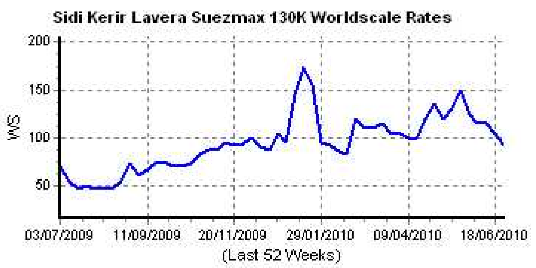
The cost of transportation will In general be the lowest in $ per ton for a large tanker and obviously most expensive for very small tankers, due to economics of scale.

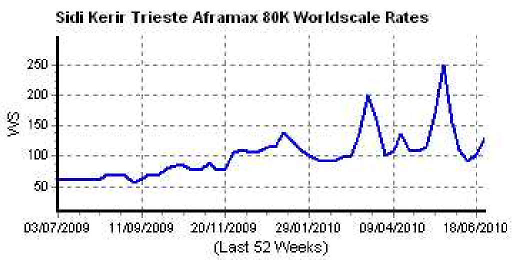
The following table illustrates the tanker classes and a very indicative cost of the daily running costs (incl depreciation).

Vessel Type	*Deadweight (tonnes)*	*approx. cost USD per day*
ULCC (Ultra Large Crude Carrier)	320,000 +	75.000
VLCC (Very Large Crude Carrier)	200,000 +	65.000
Suezmax	120,000 to 199,999	40.000
Aframax	75,000 to 119,999	30.000
Panamax	50,000 to 74,999	30.000
Handymax	38,000 to 49,999	25.000
Handy	27,000 to 37,999	25.000
Barges	1,000 to 20,000	15.000

This table simply indicates that larger capacity shipments can obtain the lowest cost for transport for any owner/charterer. Of course the final choice of tankersize used is not decided by economics only but more dominant by geological, climate and infrastructure limitations in one of the ports.

For each vessel class professional shipping brokers negotiate charterparty rates like any international market operating on a continuous price assessment basis supply and demand, like for the smaller Aframax (90.000 ton) vessel the rate is currently at 130%. The difference in rates are usually higher for Aframax to reflect the difference in shipping economics of scale between Suezmax and Aframax. Over the past year on average the difference has been around 35 WS. This translates into an extra average cost of 3.50 $/ton or 0.50 $/barrel crude freight for using Aframax instead of Suezmax vessels.(assuming a flat WS 100% freight rate Arab Gulf- Chittagong of 10.03 $/ton),.





Depending on the actual draft at Kutubdia mooring point either (small, or underloaded) Suezmax or Aframax class tankers will have to meet a draft of 16 meters., or if further out to the south the draft will improve, but at a longer voyage for the lightering vessels.

The use of underloaded vessels to meet draft is not recommended. To maintain vessel stability in case of partially loaded crude oil cargo the ships balance is compensated by increase in ballast water. In older vessels this ballast water may leak into the crude oil cargo hold and this will add undesired quantities of salt and of course water in the crude oil. And of course there is the extra freight cost per ton crude oil compared to a normal loaded vessel to maximum capacity.

BSC as owner of the lightering vessels would perform the lightering service to ERL under a term time charter arrangement where the 2 vessels in use are dedicated to the lightering operation either at a day or ton rate or monthly rental.

Currently the between BSC and BPC/ERL negotiated tariff is 5.47 USD/ton for the lightering operation. (0.75 USD/barrel). This seems quite high in light of the likely operating costs of the smaller vessel, the relative short distance and compared to other lightering operations for example at FPSO lightering in the North Sea. In perspective; the current cost for a Suezmax crude oil voyage from the AG to Chittagong would be around 110 WS or approx 11 USD/ton or 1.50 USD/barrel, so the lightering alone is almost half of the total voyage costs.

Operating costs for a 15.000 ton size lightering vessel should be no more than a range of 2.00 -3.00 $/ton (0.40 $/bbl) for a 24 hour sailing and transfer operation.

ERL's crude oil supply depends therefore on a tight and well planned operation:

1. Scheduled loading of the mothervessel, Suezmax or Aframax type, depending on the chartering costs per ton crude oil, at the loadport.in the agreed Laycan period. (36 hours
2. Sailing to the anchoring point near Kutubdia. (12-13 days at 12 knotts speed)
3. Discharge of the mothervessel at sea into the lightering (net 12000 ton) vessel. (6-8 hours per vessel assuming 2000 cbm/hour pumping and receiving capacity).
4. Sailing from Kutubdia to Chittagong Jetty 7 or 6. (5-7 hours at 12 knotts)
5. Discharge of the lightering vessels at ERL jetty 7. (7-8 hours per vessel at 1500 cbm/hour)
6. The crude oil inventory left in ERL's tanks.
7. There is no waiting for the lightering vessels either at load from the mothervessel nor the discharge at jetty 7 or 6.

Even with efficient lightering of the mothervessel and of course the uninterrupted discharge of lightering vessels at jetty 7 upon arrival, the whole sequence of events from a 130.000 ton crude oil mothervessel arrival at Kutubdia to filling of ERL's crude tanks will take at least 9 days under ideal conditions, and more likely 10 or 11 days with only 2 lightering vessels in service.

If there was no need for lightering; a direct discharge of a 130.000 ton Suezmax vessel at ERL jetty 7 or 6, would take as quickly as 36 hours at a normal discharge rate of 4-5000 cbm per hour.

However it is understood that the shore receiving capacity is only 1300-1400 cbm/hour at Jetty 7 so a discharge would then take 3 days, again assume that draft was no restriction.

In general most vessels in Aframax and Suezmax class have sufficient pumping capacity to allow 6000 tons crude oil per hour to go from ship to shore. Jetty 7 may well benefit from an upgrade in pipe diameter if larger quantities need to be discharged.

With current lightering operation the discharge of that same 130.000 tons will take 10-11 days or 9-10 days more time solely due to the draft limitations in Chittagong.

1.2. Summary of Extra Cost of lightering and demurrage of the mothervessel

Added together these extra costs for ERL to receive its crude oil are at least 11 USD/ton or 1.50 USD/barrel. (13.5 million USD/year) solely due to the draft restrictions.

1.2.1 Demurrage costs or higher charter party rates

Demurrage is an agreed amount payable to the owner in respect of delay to the vessel beyond the laytime, for which the owner is not responsible. Demurrage is normally not subject to exceptions which apply to Laytime unless specifically stated in the charter-party.

Allowed Laytime within an agreed loading period in a typical Aframax and Suezmax charterparty is usually 36 hours free for loading and 36 h for discharge. Assumed is here that loading always takes place within the allowed laytime. Time used for the voyage itself is covered by the terms and price of the transport. Any time that the vessel remains under charterers orders after 36 hours at discharge will count as demurrage time. The cost per day is always part and thus agreed in the charterparty and always close to the actual cost of the transport itself expressed per day. Currently demurrages for Afra and Suezmax class vessels are anywhere from 30.000 USD to 70.000 usd per day.

Assuming on average a demurrage cost of 40.000 usd/per day as per the average AG-Chittagong charterparty, the extra waiting days due to lightering of 10 days will mean a cost to ERL of 400.000 USD or 3.30 USD/ton (0.45 USD/barrel)

It is understood that BSC charters its crude oil vessels from owners on the basis of a 11 day allowed discharge period. The extra time over the normally 36 hours allowance for discharge is then negotiated either as part of the charter party rate or as a defined sum more or less and will be equivalent to 9-10 days of demurrage. This practice may bring some cost reduction but could also be more expensive than normal charter party agreements where demurrage occurs if time used goes past 72 hours for load and discharge. BSC was not able to provide detailed information about the charterparties rates and demurrages. However in the longer term one would expect that a professional chartering organization will minimize the demurrage cost to levels around the 3 USD/ton crude oil.

1.2.2. The Lightering operation

The cost of lightering is currently set at 5.47 USD/ton or 0.75 USD/barrel (this tariff was raised recently from 4.50 USD/ton), excluding any of the BSC commissions, if any. This amount seems very high for the short distance and it is recommended to be reviewed by BPC/ERL with BSC. ERL's alternative may well be to acquire itself a proper lightering vessel or agree on more favourable terms with BSC.

The review may take into account the actual size of the mothervessel, the size and operating cost of the lightering vessel, the speed of oil transfer, and the speed of the voyage Kutubdia anchoring point to Chittagong. Lightering with 80.000 tons vessels in the Northsea from Floating Production and Storage Operations (FPSO) with a radius of 700-800 miles will cost currently around 6 USD/ton or 0.80 USD/barrel.

For ERL it is assumed on basis of calculations as described here that it will take 10 days to lighter a 130.000 ton crude oil vessel moored at Kutubdia anchoring point, or 13000 tons per day.

Another aspect to be mentioned here is the actual daily crude oil consumption at the refinery which is now approx. 4500 ton per day. This means that ERL is not in danger because of insufficient lightering and Jetty capacity for the current ERL operation. Each lightering vessel may take a maximum of 2.5 days to complete its voyage and discharge even if crude oil stocks are low. Calculated loading, shuttle and discharge time for the lightering vessel is approx. 1 day.

However in case of the frequent poor weather conditions in the Bay of Bengal these for lightering hazardous circumstances could force the lightering to be suspended, or for the same reason if the mothervessel is delayed otherwise. The refinery will therefore need to keep a safety crude oil stock buffer into account of say 12 days to guarantee uninterrupted operations.

1.2.3 Vessel size and Economics of scale:

The cost difference between Afra- and Suezmax vessels as explained above may vary somewhat but will be around 3 USD/ton (0.45 $/barrel).

Ideally the crude oil supply to ERL should take place in normal sized Suezmax vessels (ranging between 120.000-140.000 tons for ERL), but the anchoring position may not allow the fully loaded vessels draft which is likely around 18 m. Aframax vessels are therefore an appropriate alternative although at somewhat higher cost due to higher rates. The economics of scale have been discussed above.

1.3. Possible ways to reduce the costs of crude oil transportation

1.3.1 Dredging an entry channel to Jetty 7.

In discussions with the Chittagong Port Authority it became clear that the Karnafully river and its outher banks cannot be dredged to a draft of 16-18 meters. Silt and other deposits from the Bangladesh Delta rivers and from other low level land will fill any artificially dug channel back to its current draft of 8.5 meters (At high tide). Therefore this solution is not realistic and not relevant.

1.3.2 Deeper draft anchoring points.

It is recommended to consider to choose other nearby deeper draft anchoring points in the Kutubdia region that may allow larger vessels to be used and therefore maximize at least the vessel economics of scale. This holds only if possible extra cost of lightering due to longer distance to Chittagong is minor or is not relevant. A fully loaded Suezmax class vessel in generally cheaper per ton than an Aframax as discussed by around 3.50 USD/ton. Since the cost per ton for the lightering service is already very high it could be expected that this price will not be increased if nearby deeper draft anchoring points are used.

1.3.3 Use of larger capacity lightering vessels.

Alternatively the use of larger (30.000 tons) lightering vessels that meet the 8.5 meter Chittagong draft will reduce the total overall lightering time substantially . Firstly this will reduce the crude oil mothership waiting days from current 10 to 4 days if lightering takes place with 30.000 ton capacity vessels. This will result in a lower demurrage costs or lower chartering party fees per ton crude oil. Also a corresponding cut in lightering costs should be expected with the lightering vessel economics of scale improvement.

1.3.4. Construction of a SPM

Another alternative to reduce costs is to allow vessels to anchor at a modern Single Point Mooring (SPM) facility in sufficiently deep draft waters (Kutubdia Island) and invest in larger lightering vessels or even a pipeline connection from the SPM to ERL crude tanks. Such a system needs substantial investment, but will reduce the cost of crude oil transport as a SPM+ pipeline will avoid the demurrage, the lightering and diseconomics of scale.

For this study it is understood that BPC and ERL are studying plans and ideas for a possible implementation of a SPMsystem at Kutubdia with a 75 Km pipeline connection

to Chittagong.

A few conclusions for the current crude oil supply to ERL can be made

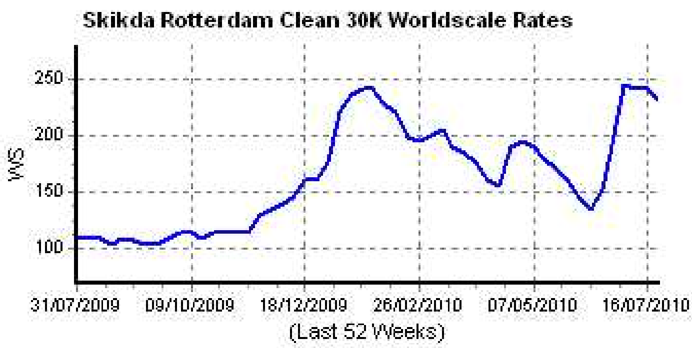
1. Draft at Jetty RM-7 is only 8.5 meters (at high tide) and cannot be dredged to accommodate larger vessels in deeper water. This draft does not permit the discharge of Aframax and Suezmax class vessels (80.000- 140.000 tons)
2. It takes a crude oil vessel of 130.000 tons approx. 10 days from arrival near Chittagong to discharge into ERL tanks, due to the lightering operation This sets the maximum crude oil receiving capacity at Jetty 7 at around 13000 tons per day. (96000 barrel/day).
3. ERL is not free to organize their crude oil supplies in the most efficient, cost and time manner. There are no easy and low cost solutions to solve the low draft problem.
4. The extra cost incurred due to the Chittagong port draft limitations is estimated at 1.50 USD/barrel or 11 USD/ton crude, with current 12000 ton capacity lightering vessels and a mothervessel anchoring point at Kutubdia.
5. Lightering with larger vessels may cut these extra costs to half, but will likely require investment in the pumping and shore reception capacity to increase the volume from current 1400 ton/hour to a more acceptable rate anywhere from 3000 to 6000 ton/hour.
6. Lightering in principle is safe if strict procedures are followed, but bears a higher risk for oil spills and other accidents.

2. OIL PRODUCTS IMPORT AND EXPORT

Imports of oil products ; Diesel, Jet fuel, Gasolines are all on a CIF delivered Chittagong basis, in cargo sizes of 30.000 tons per delivery. At that volume there is less need for lightering as some of these vessels can discharge at the oil product jetties. However there is still a need for lighterage. BPC/ERL should advise their sellers that a vessel load of 25000-26000 would prevent any restrictions on draft.

The majority of these products are bought in the Arabian Gulf.

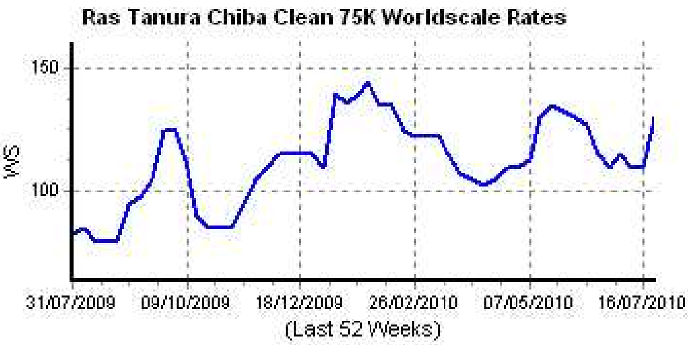
Typical freight rates for clean product vessels over the past 2 years are between 200 and 250 WS.



With a flat rate of approx. 10.00 USD/ton and average 225 WS rates this means an oil products freight cost AG to Chittagong of 22.50 USD/ton or 3.00 USD/barrel.

BPC mentioned that their main Diesel purchase contract is valued at Platts FOB AG plus a premium of 3.80 USD/barrel basis CIF Chittagong. This price is very much in line of the markets in the region and reflects the freight costs for small product tankers.

Although the decision to buy on a delivered CIF basis falls outside this study scope there is the draft limitation which prevent the use and arrival at Chittagong of larger oil product vessels. If we look only to the vessel efficiency ; 30.000 tons at WS rates of 200-250 WS compared to 75.000 tons vessels where the WS rates are between 100 and 150 WS, there is again a freight economics of scale.



Economics of scale for clean products is then approx. 100 WS points at 10.00 USD/ton flat rate for Arab Gulf to Chittagong is a freight cost difference of 10 USD/ton or 1.30 USD/barrel.

However lightering of clean product vessels is not recommended due to risk of quality deterioration and hazards like low flashpoint product exposure to air. Also lightering costs and demurrage costs are likely more than the saving on larger oil product vessel economics of scale.

The extra cost of small oil product transport however will have an influence on the refinery economics and provide an incentive to increase the refinery production and thus will help efforts for decreasing the costly imports of products.

ERL does not require transport for product sales into international markets for surplus product; Naphtha and Condensates.

Both products are sold on FOB Chittagong basis and are usually sold under tender to buyers in Singapore and Far East. We understand that the average sale price is Platts FOB Singapore basis FOB Chittagong less a discount of 2 USD/barrel . This very much reflects the actual freight cost Chittagong to Singapore for a small clean products tanker and as such does not have much impact on ERL's freight cost efficiency.

CHAPTER 3: ASSESSMENT OF ERL REFINERY TECHNICAL AND ECONOMICAL PERFORMANCE

1. GENERAL OBSERVATIONS

1.1. The Refiners Margin analysis

Although ERL is under a processing agreement with BPC it is within the agreements structure a mere cost centre and processing fee receiver. ERL also needs to be evaluated on its refiners margin performance.

It is understood from the BPC-ERL underlying processing agreement that for each barrel of crude oil processed, ERL converts that crude into an agreed deemed product yield in the Crude Distillation Unit and receives a processing fee in return. There is a separate so called extra performance fee if actual results on yield are exceeding the basic agreed yields as in the agreement. ERL also receives a crude oil handling commission which depends on the actual volume received compared to the Bill of Lading volume. For the Asphaltic Bitumen Plant operation ERL receives a small fee per ton of Residual Fuel OIL (RCO) in return. Only the operating expenses of the Secondary Processing plants are reimbursed to ERL.

The agreed yields are different for each processed crude oil type but all reflect a fair to even conservative yield to be expected from the respective ERL units.

A few data illustrate this arrangement.

USD/Taka exchange rate		68.4	68.5
ERL data		**2007-2008**	**2006-2007**
Throughput	tons	1213800	1269400
processing income	mln Taka	992.6	1101.6
	mln USD	14.5	16.1
	in Taka/barrel	110.51	117.27
	in USD/ton	11.96	12.67
	in USD/barrel	1.62	1.71
processing expenses	mln Taka	744.8	736.8
	mln USD	10.9	10.8
	in USD/ton	8.97	8.47
	in USD/barrel	1.21	1.15
administrative expenses	mln Taka	138.3	139.4
	mln USD	2.0	2.0
	in USD/ton	1.67	1.60
	in USD/barrel	0.23	0.22

The processing fee is a compensation for refining services (including crude oil and product imports handling through storage tanks, and the as separate listed fee for the Secondary Processing) and ERL earns its profit with the negotiation of the level of processing fee it will receive from BPC and its own ability to exercise cost control of its processing expenses.

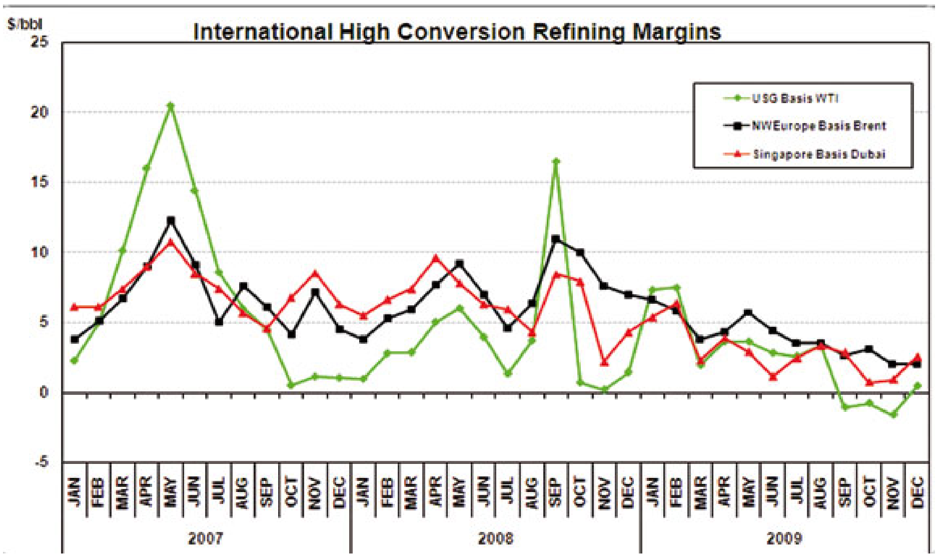
ERL operating profit/(loss)	in mln Taka	109.5	225.4
	in mln USD	1.6	3.3

The positive result is a reflection only of ERL's ability to either negotiate a good fee with BPC and / or its control over the direct processing costs, like energy use, wage levels and manpower numbers, process materials use etc.

However no assessment can be made in how far ERL would generate a positive refiners margin based profit or loss if it would have to operate as a entirely independent enterprise and buy its crude oil from the Arab Gulf producers, pay for transportation and other chartering expenses and its direct processing expenses on one side and then sell its refined products to its domestic and international customers based on a representative market value. Such refiner margin analysis is commonly done in all Western European Refineries owned by Major Oil Companies and the typical Merchant operating refineries owned by traders and specialised investment groups like in Singapore, Japan and the US Gulf Coast refineries.

Such analysis is a managerial guideline whether the operation is sustainable in the longer run.

The following graph shows for the major refining centra; US Gulf Coast, Singapore and NW Europe for typical cracking conversion (or complex) refineries over the past 5 years the refiners margin. (product revenue less crude CIF costs less operating expenses)



Source EIA : refining margins 2007- 2009

It would be incorrect to assume that ERL can be considered as being comparable to the Singapore margin (red line).

- ERL is less sophisticated than 'high conversion'cracking yield refineries,
- Above graph is very general and can only give an impression of margin trends.

The worldwide trend in the graph reflects a good period for margins from 2007 and 2008 followed by declining margins since then.

1.2. The ERL refining Margin

To judge on the specific situation for ERL and study the profitability performance the following data are important:

1.2.1. ERL Crude oil Processing and Product output data

Actual data from the past 10 years actual crude runs in ERL have been gathered and expressed as a product output yield and crude oil intake in % wt.

ERL products output and crude oil intake
in % wt

YEAR	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	Average 10 years
LPG	0.9%	1.0%	1.0%	1.1%	1.2%	1.2%	1.1%	1.0%	0.8%	0.7%	1.0%
NAPTHA	4.3%	3.1%	3.0%	4.7%	5.6%	6.6%	8.6%	9.7%	11.4%	10.6%	6.8%
MS	5.5%	6.8%	8.1%	6.8%	6.0%	4.9%	5.4%	5.2%	5.5%	4.4%	5.9%
HOBC	5.7%	5.1%	3.2%	2.8%	3.3%	3.2%	1.5%	1.0%	1.1%	1.5%	2.8%
SBPS	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
MTT	0.4%	0.4%	0.4%	0.4%	0.5%	0.6%	0.5%	0.5%	0.4%	0.5%	0.5%
JP-1	0.3%	0.1%	0.4%	0.3%	0.1%	0.0%	0.4%	0.0%	0.5%	0.7%	0.3%
SKO	23.3%	25.1%	24.6%	24.7%	25.7%	16.7%	22.2%	24.8%	21.7%	21.5%	23.0%
HSD	27.2%	24.7%	26.5%	26.0%	26.2%	32.4%	27.3%	26.4%	27.9%	27.7%	27.2%
JBO	1.3%	1.5%	1.1%	1.4%	1.4%	1.4%	1.3%	1.5%	1.1%	1.8%	1.4%
LDO	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
HSFO	24.6%	25.7%	22.6%	26.3%	24.6%	23.5%	25.7%	21.5%	23.9%	21.7%	24.0%
BITUMEN	3.9%	3.6%	5.4%	3.0%	4.5%	4.1%	4.2%	4.4%	3.6%	3.9%	4.1%
RF/Loss	2.1%	2.9%	3.7%	2.2%	0.7%	5.1%	1.5%	3.6%	1.7%	4.6%	2.8%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
ALC	47.9%	54.9%	53.5%	44.7%	39.8%	53.9%	48.0%	45.0%	45.9%	45.4%	47.9%
MURBAN	46.5%	40.5%	42.2%	50.1%	53.0%	38.1%	45.5%	45.6%	41.2%	35.8%	43.6%
CONDENSATE	5.6%	4.6%	4.2%	5.2%	7.2%	7.9%	6.5%	9.5%	12.9%	18.8%	8.5%
TOTAL	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

- The table above does form a good basis for the ERL refiners margin as this is the result in wt % of product output performance, the feedstocks used in wt%; Arab Light (ALC) , Murban crude oil and NatGas Condensate, over a long period of 10 years thereby evening out all irregularities and short term upsets.
- ERL's yield is evolving through the years. An important effect on yield is the changing crude oil slate, in particular the quantity of Condensate processed.
- Increase in the feed blend of (very light) Natural Gas Condensate during the past years tend to reduce the Fuel oil output and increase the Light Naphtha by its natural light end fractions quality difference compared with replaced Murban crude.
- The refineries ability to accept Condensate is very important, as it's the only hydrocarbon based refinery feedstock produced in Bangladesh.
- The average yield over the past 10 years represents a good basis for evaluation of the refiners margin as no major additions or removal in units have occurred .

1.2.2. International market prices and freight costs

Explanation of the Valuation methodology behind the refiners margin concept

The value of ERL's products are assessed on basis of the product purchase cost plus transportation costs to Chittagong that BPC or ERL would have to make in case there is no refinery.

BPC would buy at the cheapest location (plus arrange and add transportation costs) which for most products are either made available at refineries in the Arabian Gulf (AG), or refineries around Singapore.

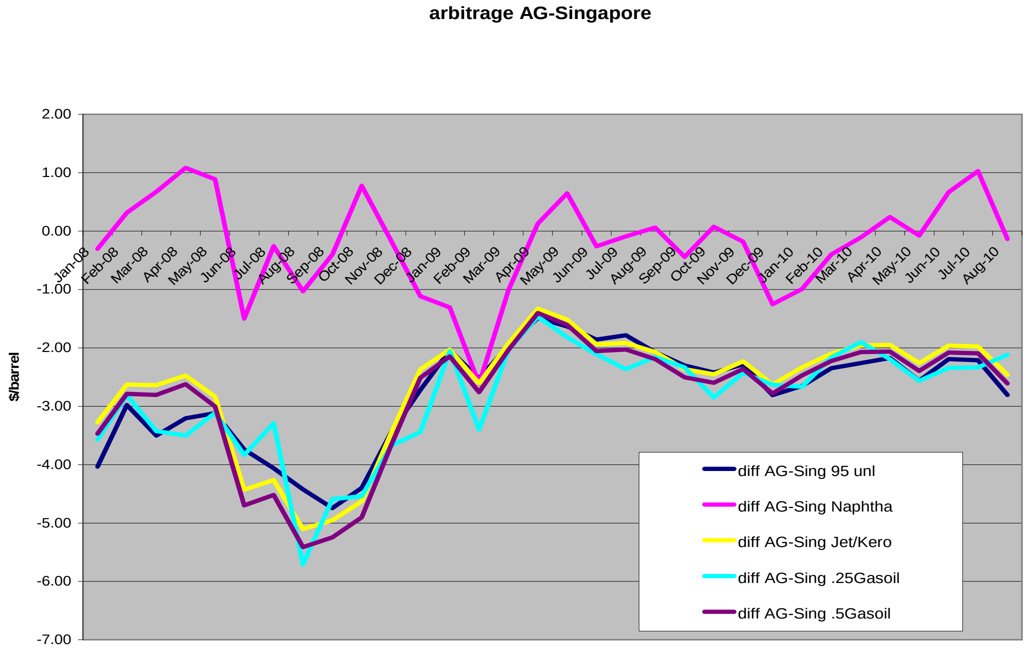
Note: Indian refiners price their products on either AG or Singapore Platts basis.

Platts FOB AG Propane and Butane prices will be used for propane and butane , which at ERL is a combined into the LPG fraction.

Singapore Platts FOB Prices will be used as product price basis for the all mainstream products from ERL refinery for this margin analysis.

Analysis of the refined product value arbitrage; the price difference between Platts FOB Arabian Gulf (AG) product prices plus a tentative vessel freight cost of 2.70 USD/barrel to Chittagong compared with Platts FOB Singapore is almost equal, except for Naphtha.

The following graph shows the product price difference in USD/barrel between FOB products ex Arab Gulf and products ex FOB Singapore :



Oil buyers in Bangladesh like BPC would naturally be inclined to buy all petroleum products (except Naphtha) on a FOB Arab Gulf basis and then arrange vessel transport to Chittagong since FOB AG prices are cheaper than FOB Singapore.

During 2008-2010 the WorldScale rate for 30.000 ton vessels (allows max 9.15 draft acceptable for Chittagong) has been around 200 WS. Flat rates AG –Chittagong is currently 10 USD/ton so actual freight costs has been 20 USD/ton with 2 USD/Ton plus/minus variance up and down and this is approx. 2.70 USD/barrel.

BPC buys also products like Diesel, Jet fuel, Kero, Gasoline 95 outright to meet the total Bangladesh petroleum product demand. This is a trading activity and prices are subject to negotiation and quality premium/discounts.

BPC current contracts for Diesel purchase is a Chittagong delivered CIF or C&F price and is based on the Platts AG for Gasoil plus a premium of 3.80 USD/barrel. Diesel quality is meeting Singapore (and European) EN590 specification therefore the premium paid of 3.80 USD/barrel reflects partly the 2.70 USD/barrel vessel freight costs plus a ‘quality’ premium of 1.10 USD/barrel.

This premium differential over Platts mean quotations is a negotiated price and is what can be expected between professional trading organisations. It is a trading activity where markets need to be compared and perhaps that same price could be obtained from a Singapore seller who will sell basis the Singapore FOB Platts (usually higher than AG), but added is a lower freight cost for Singapore-Chittagong, which is approx 11 USD/ton (1.50 USD/barrel).

Like wise BPC buys CIF Chittagong all Jet A1 aviation Fuel, and some Kerosine and all 95 octane unleaded gasolines all based on the respective Platts AG quotation plus a premium. As per latest information in May 2010 the negotiated premium were for Jet fuel and Kerosine 4.40 USD/barrel and for 95 Unleaded 7.50 USD/barrel.

All actual purchase information justifies the use of Platts FOB Singapore prices for the valuation of the main products for the refiner's margin.

Note: It is not the purpose of this assessment here to judge on the quality of BPC's trading negotiations, nor whether the current contract prices are reflecting true international market practice.

For some products there is no direct quotation and the value will be derived from other sources than Platts and derived from manufacturing differential costs, and or quality differences.

Since these speciality products are approx 6 % of ERL's output there is no major impact for minor variation in price assessments.

Therefore, here assessed prices are for:

- Solvents: Platts Singapore Naphtha plus 15 $/ton (Manufacturing cost)
- Jute batching oil: Platts Singapore Gasoil 0.25%s less 10 $/ton (quality discount)
- Marine Diesel Platts Singapore Gasoil 0.25%s less 15 $/ton (quality discount)
- Bitumen Platts Singapore HSFO plus 50 $/ton (Market price in Europe and manufacturing cost)

The arbitrage AG-Singapore is generally a very good correlation with the Platts AG prices plus the transportation to Chittagong.

This is logical as AG is an export region and Singapore is the major import and export centre, the 'hub' to the Far East; China, Japan and East Coast India. Therefore with confidence Platts Fob Singapore prices will reflect a true value for ERL products quotes for the period from January 2008 to August 2010. (see Appendix 1 for month average Platts quotations).

BPC sets on a regular basis the domestic product prices at the refinery gate; the so called ERL price, as the intercompany price between BPC/ERL and the Marketing Companies ; POCL, MPL and JOCL. The ERL prices take the relevant Platts (AG or Singapore) quotation, with then freight and other minor logistics costs added, and are then increased with local taxation.

Local taxes are based on an import tax of 12 % for products (5% for crude) with a base price of 0.31 USD/Liter (crude; 32 USD/barrel), and then a 15 % VAT tariff over the total.

The net of taxes ERL price reflects therefore the actual international market Platts based price levels, but only if the ERL price is corrected on a regular interval period, which could be on a quarterly basis to reflect the rapid changing market price environment.

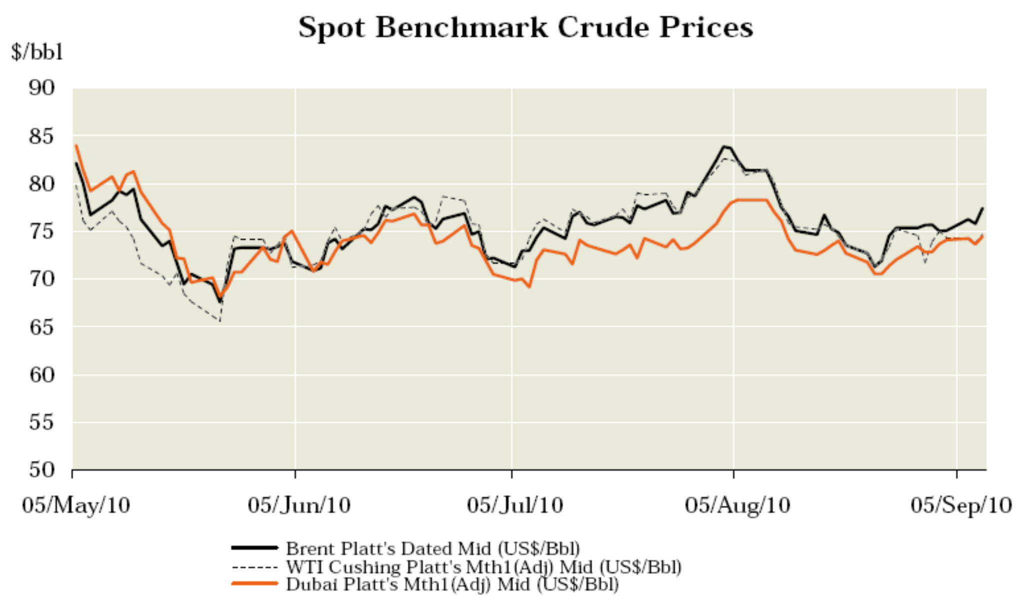
Crude oil purchase prices are based on the actual contracts currently with Saudi Aramco and ADNOC , the Abu Dhabi National Oil Company.

Both crude prices are based on the nominal posted price for regular major oil company and government agreements offtake. Platts publishes a spot FOB Murban price which reflects the ADNOC posting while Saudi Aramco sells to its Asian based customers on a formula basis the average of Dubai+Oman/2 plus or minus a premium or discount. This differential is monthly published by Saudi Aramco and has been on average over 2008 +0.55 USD/bbl, over 2009 +0.20 USD/bbl and for 2010 to August +0.30 USD/barrel.

Most other crudes are priced in their own hemisphere on basis of Brent (European), WTI (USA) and Dubai (Asia) crude.

The graph below is an illustration to show where crude oils recently were priced in international markets and the price volatility in the short term :

IEA Oil Market Report - 10 September 2010 © OECD/IEA 2010 Omr on the web: www.oilmarketreport.org



Crude and Product Price assessments are based on Daily Platts prices. ©2003 Platts - a division of McGraw-Hill Inc. - www.platts.com

BPC buys the crudes all FOB AG basis and has to arrange the transportation from the AG loadports.

Crude oil freight costs Arab Gulf to Chittagong (Kutubdia anchoring point) is based on a AFRA class vessel with an average of 130 WS rate over the past years and a flat nominal rate of 10 USD/ton.

This is then 13 USD/ton or 1.75 USD/barrel. On top will be the lightering costs of on average approx 5 USD/ton since 2008.

Both costs will be used in the refiners margin analysis.

The Natural Gas Condensate has no Platts quotation and needs to be valued by assessment of its characteristics. For this analysis the basis value is Platts Fob Singapore Naphtha less a differential of 35 USD/ton. A simple distillation reveals that this Condensate consists for 70-80% of light and heavy Naphtha's and the remainder is Kerosine/Diesel like product. The 35 USD/ton (4.50 USD/Barrel) discount is what a buyer will offer to compensate for actual shipping from Bangladesh, and some handling and refining expenses. Freight costs from the Northern Bangladesh Gas fields to Chittagong by rail and river barge is kept at approx. 13 USD/ton to simplify the analysis.

The net value of Condensate for 2009 is then according to this formula equal to 492 USD/ton, compared to Murban Fob Arab Gulf at 484 USD/ton.

1.2.3. The ERL Operating expenses.

To complement the data for the refiners margin analysis it is appropriate to use the actual ERL operating expenses. The question and comment on whether these expenses are acceptable and in line with other refineries are part of the ERL efficiency assessment and benchmark analysis.

Actual Operating expenses ERL	2007-2008	2006-2007
Taka/barrel	82.76	78.77
USD/barrel	1.21	1.15
USD/ton	8.97	8.47

The analysis will use 8.97 USD/ton being the latest full year known figure for ERL processing expenses.

1.2.4. Calculation methodology and outcome

The ERL refiners margin is the net result of:

Refined product volume valued at Platts FOB Singapore for each product

Less:

Crude oil volumes purchased at Platts FOB AG for Murban and Platts Dubai+Oman/2 plus the Aramco differential for Arab Light in the month of lifting.

Less:

Vessel transport to Chittagong (13 $/ton), incl the lighterage (5 $/ton)

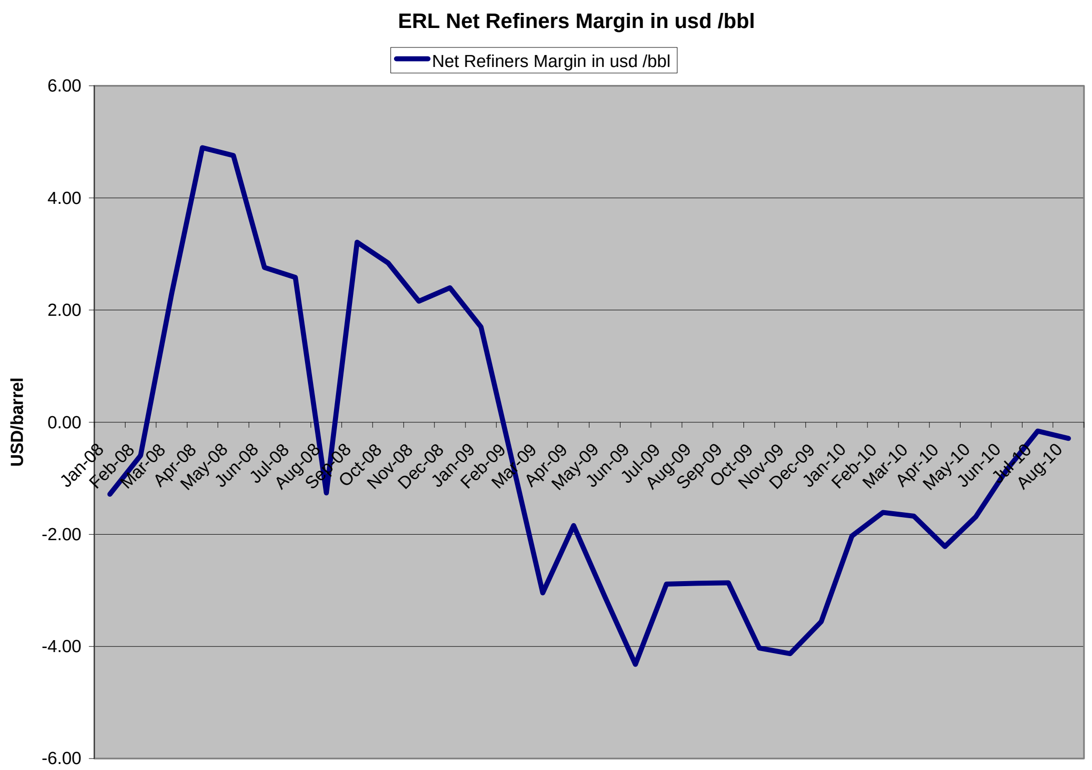
Less:

All refinery processing operating expenses (8.97 $/ton) (actual 2008)

Gives

Net refiners margin:

The results for ERL's net refiners margin from January 2008 to August 2010 are presented in the graph:



- Average for 2008: 2.06 USD/bbl
- Average for 2009: -2.64 USD/bbl (worldwide similar pattern due to recession)
- Average Jan-Aug 2010 -1.32 USD/bbl (currently September just positive)
- Overall Average period -0.54 USD/bbl

The same data are presented in a summarised year wise table :

ERL Refiners margin assessmenrt

USD/Ton

	ERL yield %wt	Average2008	Average2009	Jan-Aug 2010	Total Observed period
Products Platts					
FOB AG LPG 40/60 mix	1.0%	725.52	512.06	653.42	627.44
Sing Mogas 95 Unl	2.8%	854.99	584.85	721.29	720.26
Sing Mogas 92 Unl	5.9%	855.23	574.01	711.81	713.92
Sing Naphtha Cargoes	6.8%	769.41	526.93	663.71	652.06
Sing Jet	0.3%	954.02	550.20	685.53	735.46
Sing Kerosene	23.0%	954.02	550.20	685.53	735.46
Sing Gasoil 0.25%	27.2%	902.70	518.18	649.06	695.10
Sing HSFO 380 CST	24.0%	495.66	367.69	456.97	438.00
Solvents	0.5%	784.41	541.93	678.71	667.06
Jute Oil	1.4%	892.70	508.18	639.06	685.10
Marine Diesel	0.2%	887.70	503.18	634.06	680.10
Bitumen	4.1%	545.66	417.69	506.97	488.00
Cons/losses	2.8%				
Total refined product value	100.0%	761.25	476.48	594.13	612.68
Crude Platts AG					
fob AG Arab Lt	47.9%	687.06	451.25	553.40	565.22
fob Murban	43.6%	751.25	484.15	592.66	611.44
NatGascond (=Na-35$/t)	8.5%	734.41	491.93	628.71	617.06
Total Crude oil cost	100.0%	719.02	469.02	576.89	589.74
Freight Ar lt, Murban	Afra AG-Kutubdia	13.00	13.00	13.00	13.00
Lightering		5.00	5.00	5.00	5.00
Gross Refiners Margin		24.23	-10.54	-0.76	4.94
ERL Operating expenses	incl deprec	8.97	8.97	8.97	8.97
Net Refiners Margin	**in usd/ ton**	**15.26**	**-19.51**	**-9.73**	**-4.03**
Net Refiners Margin	**in usd /bbl**	**2.06**	**-2.64**	**-1.32**	**-0.54**

The following conclusions can be derived from this analysis:

- Although the observation period is relative short, just 32 months the results are quite volatile. This typically reflect international Oil Markets where market circumstances and thus petroleum product and crude oil prices will vary from month to month.
- There is no guarantee where margins will stabilize, and for how long, if at all.
- Year 2008 was for most European, US and Far Eastern refiners, thus also for ERL a positive year, while worldwide recession dominated the years 2009 and 2010 with depressed demand and therefore lower product prices.
- ERL net refiners margin over the 32 months period is just Break Even to slightly negative at 0.54 USD/barrel.
- Relative higher costs at ERL; refinery own fuel consumption and losses and less efficient crude oil freight plus lightering are a factor for the current ERL margin potential but compensated by the Visbreaker and Bitumen upgrading uplift.
- The operating expenses would not be much lower if without the refinery operation as Bangladesh would have to import all its products and that requires handling and storage and distribution facilities in Chittagong which would still be needed.

- Refining margin history should not be the only decision point to build and operate refineries, but should guide decisions on investment in conversion units and in improved efficiencies and variations in crude oil type feedstock slate.
- ERL should benefit from better margins than the recent ones over 2009 to mid 2010 as economic recovery will set in and product demand across Far Eastern economies will increase.

It is impossible to make a judgement about ERL's refining margins for future months as market prices for crude and products cannot be predicted. Comparison with other refineries is also not possible because:

- Yield structures are different due to operating practices, even if there is an identical configuration.
- Refineries run different crudes pending their economics, availabilities and process unit design.
- International market prices are different in each major refining location, due to arbitrages between import and export regions and/or because of unique locations.
- Different refinery configurations make comparisons worthless. More complex refineries will have better refining margins than relative simple configurations.

2. THE ROLE OF ERL AND PETROBANGLA GAS SEPARATION UNITS FOR NAT GAS CONDENSATE AND NATUTAL GAS LIQUIDS PROCESSING

The Natural Gas Liquid (NGL) and Natural Gas Condensates (NGC) are both a very light hydrocarbon stream that are generated as a byproduct from the Natural Gas production fields operated by Petrobangla and foreign company operators.

NGL streams are essentially Propane and Butane or LPG with a small proportion of very light Naphtha. Condensates also contain Naphtha, Kero and Diesel fractions.

All the NGL and NGC is treated at the field in Gas-Liquid separator plants at Kailastilla and other. The LPG is routed to the nearby bottling plant operated by LP Gas Ltd. The marketing companies POCL, MPL and JOCL sell the LPG via their distribution channels in the Sylhet province as well as the Light Naphtha stream which is sold as a low octane gasoline. In 2008 Petrobangla produced 15000 tons of NGL's.

The gasfields also produce NGC, a more heavier liquid formed as a result of the high gas reservoir compression. This Condensate has a specific gravity of 0.780 and distilled its fractions are 60-70% Light Naphtha, 10-20% Kerosine and the remainder is Diesel. (source: PetroBangla test report 24 September 2009)

2.1 Nat Gas Condensate treatment

Some of the Condensate is treated and distilled with the NGL's at Kailastilla plants 1 and 2 and the products; low octane Gasoline, Kerosine and some Diesel is sold by the marketing companies. Most of the condensate however is transported with coastal tankers to ERL refinery, after first treatment in the gas-liquid separator to remove the LPG and lighter components. This treatment increases the initial boiling point to 50º C for safe transportation in railcars or lorry if possible.

The Government has set the domestic price for NGC currently at 41 Taka/per litre. Recalculated this is approx 695 $ ton, and close to the current Naphtha Fob Singapore quotation of 700 $/ton.

Petrobangla at current market price circumstances obtains therefore a good revenue by selling to ERL at 41 Taka/ltr. ERL in its turn cannot add much more value as most of the Naphtha is exported at a price very close to the Condensate purchase price.

Production of GasCondensates **23/09/2010**

	barrel day	Ton/year
PetroBangla affiliates	1771	80802
Chevron	4552	207685
Other IOC	399	18204
total	6722	306691

Source: Petrobangla web site

PetroBangla processes some of the Condensate at their Kailastilla site, in year 2008-2009 this was approx 24000 tons. ERL received the remainder to a volume of 245000 tons. Petrobangla converts the light naphtha into a low octane gasoline and the kero as a Diesel which is sold locally.

The average expected yield from the total local Nat Gas Condensate at **current (as per Petrobangla data)** 300.000 ton year production is:

- Light Naphtha 65% wt 195.000 tons
- Kerosine 20% wt 60.000 tons
- Diesel 15% wt 45.000 tons

These volumes are quite substantial and will continue to grow moderate (2-3% per year) in line with Nat Gas production to 2020.

The yield however is far from ideal as most of the condensate is returned from distillation as light naphtha which is exported from Bangladesh since demand from Petrochemical industry is not present. Neither can ERL make use of this Naphtha without specific process units like an Isomerisation unit.

Furthermore NGC is difficult to process in any refinery due to its large volume of very light ends and no fractionation tower bottom residuals. Such feedstock processed in a crude unit will limit the overall throughput capacity in the Crude Distillation Unit, as the overhead condensation capability is reaching its limitations earlier with large amounts of light Naphtha.

A direct blend or spike of condensate into Murban and Arab Light crude is therefore limited to maximum 8 % for that reason. ERL currently processes NGL's at a rate of 20% of the total crude mix, as most of the condensate is processed in the MHC/Hydrodesulphurisation unit fractionation tower which is entirely separate from the Crude Units main distillation tower.

However this condensate processing route will disappear if ERL decides to restart the Hydrodesulphurisation unit for sulphur removal or upgrading of vacuum gasoils.

2.2 Observations and Remarks

1. NGC processing represents 20% of the ERL crude oil slate.

2. At approx 250.000 ton/year, ERL is close or already at its maximum ability to process NGC. Any increase will seriously limit the crude processing volumes.

3. The Kailastilla plants 1 and 2 have capacity left but need reliable power electricity supply which is not there now according to Petrobangla.

4. Increase in Natural Gas Liquids processing will quickly absorb the surplus capacities at these plants.

5. Kailastilla plants 1 and 2 can handle a maximum of 100.000 tons per year of NGL and NGC combined according to Petrobangla.

6. Most of the Condensate is light Naphtha, which is exported with ERL's own light Naphtha volumes from crude distillation at Platts FOB Singapore Naphtha less 2-3 USD/barrel.

7. Conversion of Light Naphtha into good quality Low Octane Gasoline (MS) requires processing in a Isomerisation unit.

8. Petrobanglas MS gasoline quality is unlikely to meet minimum unleaded MS Premium specifications on Octane (RON 95), and other points. MS Regular Octane is set at 80 RON, and can be marginally met but without tank testing procedures.

Though local Condensate is of enormous value to the petroleum products supply in Bangladesh, it is also putting restrictions on the ERL and Kailastilla processing units, in particular the available overall maximum processing capacity.

Condensate generally has a good value for the Petrochemical industry if exported as naphtha cracker feedstock with matching specifications (likely close to Platts Singapore Naphtha plus a premium).

This will bring the revenue back into Bangladesh and allows at the same time better throughput at ERL of its crude oil distillation unit capacity. Processing more of the Condensate at ERL will not add much value as the light naphtha is exported, and ERL is limited by the normal design restriction in its Crude oil fractionation if more Condensate is added to its crude oil slate above 8% or equivalent to 100.000 ton/year.

3 ERL THE REFINERY EFFICIENCY RATING

3.1 ERL Energy use

Refinery Energy consumption, furnace burner fuels and power, steam generation fuels is a complex issue. The purpose of this section will be to assess the quality of the energy handling and consumption at ERL. However to make that judgement and comparison is far from straightforward as differences will occur :

- Each process unit requires a different quantum of energy. A CDU requires less energy consumption per barrel intake than a Platformer.
- The size of the unit is important as it sets economies of scale; the smaller a unit is ,the less efficient it generally is. ERL has small sized units.
- The operating mode and crude oil types. Lighter crudes require more fractionation energy than crudes with low distillation yields.
- Power generation technology at the site; Combined Heat+Power Gasturbines high efficiency (60-70%) compared with low efficiency (30-40%) from conventional fired steam boilers.
- Outside ambient temperatures, Location, climate.
- Utilisation of waste gasses; Flare controls.

For the ERL energy consumption assessment it is appropriate to use a per barrel Standard Refinery Utility experience data, which is a actual data based average for over 200 different refineries with per unit/barrel average furnace fuel oil consumption, steam and electricity generation, and cooling water data .

Standard Refinery 100.000 bbl/day
Utility data (per bbl unit feed)
consumption (Gary and Handwerk, Petroleum Refining ed 3)

per barrel crude	steam	power	cooling water	fuel	H2	furnace kwh	furnace kwh
	kg (300psi)	kwh	cbm	kJ	Mscf	per bbl	per ton
CDU	4.5	0.9	0.6	52750		14.7	96.7
VDU	4.5	0.3	0.6	31650		8.8	58.0
VBU	14.0	1.2	0.3	147707		41.0	270.8
CRU 102	13.5	3.0	2.3	316500	-8.0	87.9	580.3
Isom	0.0	1.0	2.4	211000	0.0	58.6	386.8
HDS	4.5	3.0	1.9	158000	0.5	43.9	289.7
mild hc	33.0	13.0	1.7	215000	2.0	59.7	394.2

Each ERL unit is almost always run at the maximum rated capacity, and therefore the ratings as per the table above are multiplied with these capacities to arrive at a theoretical expectation of ERL use of furnace burner fuel.

These numbers are then compared to the designed actual ratings and will lead to an estimated degree of efficiency of the various ERL units furnaces.

3.2 ERL furnaces performance

ERL Consumption/loss

unit cap bbls/day		steam Ton 300psi/day	power MWh	cooling water cbm/day	(Calculated) Energy to Furnaces Fuel tons/day required	(Calculated) furnace MWh capacity required	furnace Kcal/h heat duty capacity actual	furnace MWh capacity actual	Estimated furnace efficiency
33000	CDU	148.5	1.2	19140.0	37.2	20.1	25439000	29.6	68.1%
4000	ABP(VDU)	18.0	0.1	2280.0	2.7	1.5	5700000	6.6	22.2%
10000	SCP(VBU)	140.0	0.5	2600.0	31.6	17.1	14808000	17.2	
1700	CRU 102	23.0	0.2	3910.0	11.5	6.2	5525000	6.4	
2000	HDS	9.0	0.3	3800.0	6.8	3.7	2200000	2.7	
	total units	338.5	2.3	31730.0	89.7	48.6	53672000	62.5	77.8%
	Fuel Consumption as %wt Crude intake				1.98%				

The estimated ERL burner fuel consumption for the process units is 1.98% wt on crude oil intake. ERL actual burner fuel use over the past 3 years is around 2.3 % and is thus well in line with the expected outcome on burner fuel use. The difference is also partly caused by the use of Diesel fuel for the 2 MW Diesel electricity generator engine, which is not included in the above data. This is approx 0.15% on crude intake.

The overall burner fuel use gives an estimated efficiency for the furnaces on average of 77.8%, which is a good result. The main contributors are the Visbreaker with nearly 100% efficiency, probably too high but it points towards a very good heat exchanger system combined with an efficient furnace and maximum use of excess heat in the convection zone.

This result will allow the furnace to reach higher throughputs as well if required.

The Crude Distillation Unit furnace is close to 70 % which is good but may require some adjustment in the furnace convection section. It is likely that the top of the furnace is slightly too high in temperature.

The results for the HDS unit is incorrect as the furnace is used for heating and fractionation of the Condensate stream only and not for the actual reactor section which is shutdown. Likewise the Asphalt /Vacuum unit scores low but this does not include the full burner fuel use for the Bitumen section of the plant.

However it is likely that the furnaces size of the ABP complex is large and required for the current operation because the feedstock is fed from relatively cold tanks instead of direct feed from 350 deg C atmospheric crude unit bottoms.

3.3 ERL Electricity and Steam generation.

ERL requires on a daily average basis approx 2.4-2.6 MWh for its processing units and 0.9 MWH for utilities and other off site facilities therefore a total of 3.3-3.5 MWh electricity demand per hour.

Expectation (see table ERL consumption/loss above) for all its process units is a requirement of 2.3 MWhr and is thereby exactly in line with actual demand from the process units.

Process steam requirements depend on the actual operational situation at ERL, but on average the daily required use is 200-250 ton per day (10 ton /hr).

This is low compared with the calculated expectation of 338 ton per day. The difference may well be explained by each process unit steam injection requirement and other normal process variables. Also due to the ambient temperature there is hardly any need for steam tracing of pipelines and storage tank coil heating. There is a large demand in colder climate located refineries for this servicing of refinery logistics which is not required at ERL.

3.4 ERL utility performance

Power unit		fuel use per hour	Electr output MWhr	steam output ton/hr	Estimated furnace efficiency
Steam turbine gen 1	Gas Ncbm/hr	1200	2.20	10.0	31.8%
Steam turbine gen 2	Gas Ncbm/hr	320	0.56	2.6	30.5%
Boilers	Gas Ncbm/hr	0		0.0	73.0%
		1520		12.6	
Diesel Generator	Diesel liter/hr	285	0.95	0.0	32.9%

At the time of the visit to ERL's power section both the conventional gas fired Steam Turbine Generation plants (STG 1 and 2) were in operation as well as the Diesel Generator. Total electricity generation name plate capacity is 8 MWhr, (STG1 and STG2 each 3 MW and the Diesel generator 2 MW), well above the current requirements of 3.5 MWh.

However the gas fired steam generators and the Diesel generator are based on conventional technology and have efficiency between 30 and 35 % as can be expected from such units. Power supply could be made available at much more efficient rates, well into 60-70 % but to achieve such rates of efficient energy use would require a complete new investment in Combined Heat and Power Gasturbine installations. Use of such equipment would halve the cost of ERL's Electricity and Steam production, but requires investment.

Conventional technology may also present risk of unscheduled shutdowns in electricity supply. Although ERL could maintain the operation of its main process units if one generator is shut, there is a risk when the remaining generators are required for longer periods to run at full generator output.

Actual process steam production is approx 12 tons per hour, from both steam generator (boiler) plants. This is what can be expected and the efficiency is in line with above described expectations.

In ERL annual report there is a processing expense of 117.3 million Taka (1.7 million USD) for purchase of Bakhrabad gas. This expense which is 16% of all processing expenses then reflects ERL's total gas consumption as burner fuel for the utilities to 19.5 million Ncbm per year. (assumes a current gas domestic price of 5.9 Taka per Ncbm.). In oil equivalent the gas use is on daily basis approx. 44 tons per day or 0.9 % on crude oil intake.

3.5 The Flaresystem

There are no installations in place to utilise the gas that is routed to the Flare. This is for ERL and so many other refineries a normal operation and quantities of flared gas are not directly measured or controlled.

The knock out drum where spent and by process unit discharged hydrocarbons are captured before entering the stack is the only safeguard against overflows and potential explosive circumstances if a sudden emergency forces gas and liquids out to the air. ERL may have to review its operation here and convert a major part of the flared gas into usable energy.

3.6 Energy efficiency conclusions

ERL process unit furnaces and its utility section are performing to expectations without great losses or major inefficiencies. However the utility facilities are based on conventional equipment and quite spectacular efficiency gains could certainly be possible with investment in more current technology. Likewise some of the furnaces, CDU and Vacuum Unit may need some closer examination to marginally improve the heat transfer and convection efficiency, but due to the small size of ERL's processing units in general economies of scale are to a great extent unlikely to be achieved.

ERL's overall use of energy for processing units over the past 3 years is approx 2.3% compared to an ideal expectation of 1.98% . The actual use of burner fuels is reasonably efficient which is reflected as a cost to ERL of 10.50 USD/per ton crude intake or 1.42 USD/barrel. (this is the 2.3% refinery fuel consumption multiplied by 457 USD/ton; the average of past 3 years Platts Singapore HS Fuel oil quotation).

But savings can be made as discussed above.

Note that the energy use cost is taken into account in the refiners margin calculation above as a non valued product yield percentage and therefore it is a cost yield element.

4 ERL PRODUCT QUALITY SPECIFICATIONS COMPARED TO NEIGHBOURING REGIONS

4.1 Introduction

Governments and other professional organisations in most countries have defined minimum and maximum specifications which Petroleum products should meet.

Apart from typical driveability product specification and its requirements like Octane Number, Cetane Index and calorific value, most specifications are driven by environmental concerns with respect to air, water and ground pollution. Typical examples are sulphur content, metals like lead, manganese, aromatic compounds like benzene, olefins, and oxygenates content.

Over the past 20 years these specifications have forced refineries worldwide to modernise and adapt their facilities to meet much stricter standards in the major consumer centres and regions. Quite large investments, over billions of dollars, have been made on desulphurisation units capable to remove sulphur to levels like 10 ppm for Diesel and Gasolines, on process units to eliminate benzene from Gasoline by new Platformer designs and other processing methods and elimination of hazardous compounds such as lead as octane improver.

Besides these strict specifications most countries have stricter limits on carbondioxide and sulphur emissions which force refineries to burn cleaner low sulphur and thus more expensive fuels in the furnaces.

Bangladesh seems one of the very few countries where no policies or regulation has been in place with respect to support of some kind of strict product specification. Though it is not this refinery assessments goal to interfere with local governmental ideas about environment, there is a necessity to protect the countries people against products that can cause hazards for health and safety.

It is understood that ERL and BPC have voluntarily issued a sort of manufacturing specification for the petroleum products produced.

ERL laboratory issues certificates of quality from each tank batch that is released for sale, but these certificates do not maintain certain min/max limits on some of the important specifications.

ERL's on site laboratory performs key tests on all product streams; density, vapour pressure, distillation, mercaptan doctor tests and performs a range of routine tests for all finished products.

This however does not imply that there is a routine and standardised quality verification against a mandatory specification issued by itself or imposed by others, which may cause a finished product tank to become off spec because it may violate a minimum/maximum limit.

The table below lists the most important specifications that are mandatory in most listed countries in this region, like India, Thailand, Philippines, Malaysia, and to many aspects Bangladesh. These limits are compared with actual ERL certificate sheets.

4.2 Key petroleum product test specifications

		Europe	Singapore	USA	Bangladesh ERL
Naphtha					
Paraffins	%vol	65min	65min	70 min	70 min
Doctor test		Negative	Negative	Negative	Positive
Lead	ppb	10 max	150 max	10 max	30
Vapour Pressure KPa		90 max	90max	70 max	103 max
Gasolines unleaded					
Octane Research		95,92min	95,92 min	95,92	95
Benzene	% wt	1 max	5 max*	1 max	<5
Sulphur	ppm	10 max	500 max	10 max	250
Oxygenates	%wt	2.7 max	14 max	10 max	NA
Aromatics	%wt	35 max	report*	35 max	NA
FBP	C	210 max	225 max	210	210
Vapour Pressure KPa		70 max	70 max	45max	85
Jet Fuel A1					
Defstan 91-91 ***		conform	conform	conform	no production
Kerosine household					
Distillation IBP C		Dual purpose	Dual purpose	Dual purpose	160
Smoke point	mm	25 min	25min	25min	20
Flash point	C	38 min	38 min	40 min	40
Sulphur	ppm	3000 max	3000 max	3000 max	2850
Diesel					
Cetane Index		46min	48 min	48 min	50
Sulphur	ppm	10 max	500 max	10 max	2800**
Cloudpoint	C	-5 max	0	-5 max	NA
Flashpoint	C	55min	66min	66 min	39

* Unleaded 95 Singapore Gasoline will meet benzene to max 1.5% in 2012 and likely together with sulphur limits of 50 ppm.

** After blending with imported Diesel. Sulphur in ERL produced Diesel without hydrotreatment is estimated between1.0-1.75% (10000- 17500 ppm)

Singapore Diesel quality has three sulphur specs, 10, 50 and 500 ppm. The 500 ppm grade is the most widely traded.

*** DERD 2494 UK standard or DEFSTAN 91-91 standard. Equal limits.

4.3 ERL limitations in meeting specifications

ERL current configuration does not allow any improvement in product quality, because major units that control product quality are not there; like a proper sulphur removal Hydrodesulphurisation unit, a Platformer benzene removal unit or with alkylation or BTX units, or Isomerisation unit.

This means that ERL has to invest in equipment and change its mode of operation quite drastically if the Bangladesh Government or any other competent body imposes stricter product specification limits on petroleum products sold in Bangladesh. Alternatively Bangladesh has to shut the refinery and will have to rely on imports from the Arab Gulf or Singapore refineries depending on the degree of limitation.

From the summarised specification listing above ERL and Bangladesh in general would likely be associated with Singapore regional type of product qualities.

Currently ERL (and Petrobangla Kailastilla 1&2) cannot produce the following key product qualities from own production:

- sulphur 500 ppm or lower in Diesel.
- 95 octane and 50 ppm sulphur in Gasolines.
- Aromatics (Benzene) max limits in gasolines.
- Not always routinely meeting min and max distillation specs for Kerosine, and Diesel.
- Flashpoints and vapour pressure limits.

As long as the Bangladesh petroleum product market remains without mandatory min/max limits there is no reason why ERL would be compelled to improve product quality.

However if Singapore (and or Middle East) type of limits are adopted for the Bangladesh markets then ERL will have to invest considerable amounts in desulphurisation and de-aromatisation units to comply with these requirements.

Note that the available Merox units do not remove sulphur adequately from the product and is altogether not the appropriate process for sulphur reduction leading to 500 or lower ppm limits.

4.4 Assessment of current ERL Diesel/Naphtha Desulphurisation

The current small 1600 barrel/day desulphurisation/annex converted mild hydrocracker reactor has not been in operation for many years.

However if that unit is revamped and brought back in ordinary desulphurisation service (not as Mild Hydrocracker) the maximum throughput capacity is only capable to process less than 20% of the total Diesel daily intermediate rundown production.

Also the outdated design of this unit will unlikely to be capable to remove more than 80% of the sulphur in the Crude Unit's distillate fraction, which then leaves still 0.3% (3000 ppm) in the finished grade ERL Diesel, assuming the current crude slate is unchanged.

If ERL would need to produce a 500 ppm Diesel then a new build facility with at least 5000 barrel/day capacity is inevitable. The unit would also be required to treat the Visbreaker distillates for sulphur and for conversion and removal of unwanted aromatics and other instabilities.

Such unit will operate at pressures well above 50 kg/cm2 and uses a cobalt molybdenum reactor catalyst with overall design inclusive of dedicated amine absorber treatment and regeneration units and a sulphur recovery unit.

The current ERL Platformer section operating Naphtha desulphurisation for preparation of feed to the Platformer would be capable to produce a 50 ppm Platformer feed subject to increase in operating pressure without much modification required. This assumes that current untreated Naphtha feed to the Platformer is less than 500 ppm.

4.5 Assessment of ERL aromatics removal capability

Benzenes in Gasoline are mostly removed by

1. Proper distillation of light straight run Naphtha to include all C5 and C6 from the Heavy Naphtha Platformer feedstock. ERL has a Naphtha stabiliser that should accommodate this split. Removal of Pentane and Hexane's is the simplest and cheapest way to limit the formation of benzene rings in the Platformer.

2. Increased severity of the Platformer operating pressure to form multiple aromatic bonds instead of benzene rings. ERL should run tests on this. See also the technical due diligence chapter about increase in severity for better octane number performance.

3. Redistillation and separation of any formed benzenes from the Platformate fraction in the Platformer stabiliser and splitter. Benzene (and Toluene Xylene) rich streams have a higher value in international petrochemical markets than Gasoline.

ERL should have the basic setup for benzene removal with its current configuration but will have to address operating parameters in a well planned test run setup should it want to start to remove benzenes to lower levels. Current actual benzene content in ERL produced lower octane gasoline will most probably vary between 2.8 and 5 % depending also on the crude oil quality and the end point or inclusion of C5 and C6 in the light Naphtha stream.

4.6 Production of higher octane gasoline

In the due diligence section a higher octane mode of the Platformer operation is suggested. ERL Platformer should be able to accept an increase in severity leading to a higher Research Octane Number in the Platformate. Such operation, if possible by design also will lead to more frequent regeneration of the Platformer catalyst.

Economics supported by Singapore Platt's Gasoline prices fully justify an increase in severity.

The evaluation is based on an increase in pressure to 50 kg/cm2 in the three Platformer Reactors, with an operating temperature around 500 degr C. The expected Research Octane number (RON) will rise from current 88 RON (basis todays conditions at 35 kg /cm2) to an expected 98 or even higher RON at higher severity. Reformate output yield are expected to remain around 85-86% as higher severity in pressure also improves the conversion of naphthenes into aromatics instead of forming LPG and other refinery gasses. A 98 RON reformate can then be blended with additional volumes of light Naphtha (and even some Butane depending on volatility or Reed Vapour Pressure maximum specification) which then all is upgraded to produce a 95 unleaded Gasoline grade.

Due to higher severity in the reactor the catalyst will loose its activity after a period of 6 months or longer. Regeneration by burning the carbon deposits and chloride preparation will take maximum of 14 days per regeneration cycle. During that period it is assumed that the Platformer feedstock; Heavy Naphtha will go to tank and be sold at Platts Singapore FOB prices less 2 USD/bbl.

	Increase Platformer severity for unleaded 95 Current Reformate octane 88 Ron, unleaded 95 imported				
Platts Apagscan					
Fob Singapore	06/08/2010		mean $/bbl	$/ton(calc)	
Gasoline 95 unleaded			86.78	722.88	
Gasoline 92 unleaded			85.14	715.18	
Naphtha			75.36	655.63	
freight Sing-Chittagong				11.00	
Calc Octane value 1 RON				2.57	
Calc differential value 95- 88 gasoline				17.97	
ERL Platformer 70000 ton/year	days	tons			
reformer octane benefit days	351	67392		28.97	$1,952,341.75 per year
regeneration cost					
Gasoline 88 lost, Naphtha export	14	2688		60.28	$162,020.45 per year
Net benefit					$1,790,321.29 per year

The above calculation is based on Singapore Platts values of 6 August 2010, and does not include the advantages of blending lower value light naphtha into 98 RON reformate. It is solely a comparison of the at ERL produced 95 unleaded gasoline less the cost of not producing 88 RON reformate which now becomes after blending a 92 RON gasoline. The calculation assumes that higher and lower octane gasolines can both be produced at ERL.

Of course the quality and integrity of the Unit under increased severity must be tested and approved by the designer. Also economics may change with changing Platts prices.

However the Platformer capacity of 1700 barrel/day (70.000 ton/year) is very small to make a realistic attempt to satisfy the all local demand with own 95 RON unleaded gasoline production besides the demand for regular 92 RON gasoline.

4.7 Production of Jet Fuel A1

ERL technically can produce with its current configuration Jet Fuel A1 quality.

There is no specific manufacturing requirement other than to comply with DEFSTAN 91-91 and or DERD2494 specs, which can be met by adjusting the fractionation parameters and addition of specific additives.

Producing Jet A1 aviation fuel is merely a thorough parameter adjustment process in the Crude Distillation Unit, specification control and of course additivation.

However ERL is today forced to concentrate on maximum SKO production due to the high demand for household kerosene, a grade similar to Jet Fuel. To maximise Kero output some of the Naphtha is included in the fraction, thereby violating the Jet Fuel specification. Put otherwise, ERL production of Jet Fuel instead of household kerosene would result in a much higher Naphtha output than can be processed in the Platformer, and would also generate more light naphtha to be exported.

Over the past years the (international market) value of Singapore Platts Kero (Jet Fuel and duel purpose Kero) is well above the Platts Naphtha (by 18 USD/barrel) and Gasoline (by 9 USD/barrel) quotations.

Therefore from an economic perspective ERL is maximising its highest priced product and follows the correct decision to purchase and import its Jet fuel requirements.

ERL also benefits from a fully additivated Jet Fuel, which otherwise would have to be arranged for at the refinery and or airports.

5. POSSIBLE VARIATIONS ON THE CURRENT ERL MODE OF OPERATION AND REFINERS MARGIN EFFECT.

5.1 Introduction

ERL has a relatively small capacity for the Crude Unit and Vacuum Unit, Platformer and Desulphurisation Unit and this combined with a rather simple configuration and with only the moderate severity Visbreaker as secondary processing unit does have some limitations.

The ability to process different crudes and obtain the maximum value from these crudes are not pursued with the existing configuration.

Operating flexibility and process efficiency at the lowest costs are important factors for any refinery to meet both its customer demand and generate a positive refiners margin to enable a continued operation based on sound economic principles. From the refiners margin analysis it has become clear that margins are rather volatile and for ERL going from positive into negatives within relative short periods.

The Nelson index comparison only judges on pure technical performance. Although deep conversion refineries generally do provide better product yields, they are also much more expensive as investment in secondary upgrading is requiring a multitude of capital compared to the cost of a atmospheric and vacuum distillation unit. A new build 70.000 barrel day Cat Cracker operating at Vietnams Dung Quat refinery costs over 350 million USD to build (excl supporting and off plot units)

Also deep conversion refineries are at much higher operating expenses, like process materials , catalyst, maintenance and much higher own fuel consumption and losses, than relative simple configured refineries like ERL.

In today's crude oil supply and trading environment the price difference between light, low sulphur crudes and heavy high sulphur high acidity crudes is much higher recently than 10-15 years ago. Most participants expect these price differences to widen even further. This crude oil cost differential has been the main driver for the increase in secondary upgrading units on a world wide basis. Countries like India and China have both significantly invested in deep conversion in just the last 10 years.

ERL with its **current configuration** could still consider:

1. Change in operating conditions in its only conversion unit, severity and residence time
2. Change in crude oil slate, heavy cheap crudes compared to more expensive light crude.

5.2 Assessment of possibilities for changing operating conditions in ERL refinery.

Deep conversion refineries can process heavy and therefore cheap crudes and still return a high gasoline/ distillate process yield but with an instant major decreasing effect on the cost of their crude oil supply. Heavier crudes produce more Residual fuel oil but conversion units like the ERL Visbreaker and operated as a Thermal Cracker at higher temperature and pressure can successfully convert part of the extra Fuel oil to distillates.

ERL has just one conversion unit, the Visbreaker. The unit capacity of 522000 ton year (10500 barrel/day) is run on very moderate parameters and produces 16.5 % Naphtha and Diesel intermediate streams.

With a value differential of 257 $/ton between Diesel/Gasoil and Residual Fuel oil (2008-2010 average Platts Singapore differential) the Visbreaker contributes its upgrading value over the 16.5 % conversion to ERL, which is approx 22.2 million USD/per year. Per barrel crude oil processed this is equivalent to 2.35 USD/barrel.

In other words, if ERL does not operate or would not have this conversion ability, the overall refiners margin would have been 2.35 USD/barrel crude lower, and well over 2 USD/barrel negative over the observed period.

It is obvious that conversion needs to be emphasized for any refinery as just crude oil distillation is at negative margins.

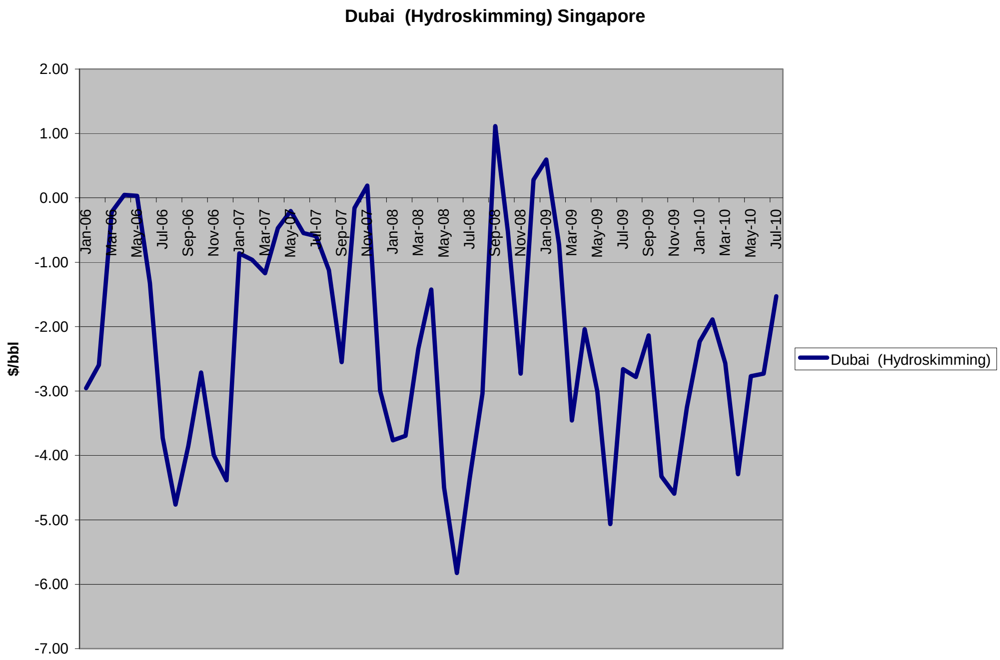
Visbreakers are the simplest conversion plants, while Resid Cat Crackers and Resid Hydrocrackers are latest generation technology units.

A typical Resid (two stage) hydrocracker converts 80 % residual Fuel oil into Kerosene and Diesel. With the same value differential between Diesel and Fuel oil of 257 $ ton as used for a Visbreaker, the Hydrocracker running on residual fuel delivers an upgrading of 10-15 usd/ per **barrel crude oil.**

A Resid Cat Cracker converts a paraffinic Residual Fuel oil into 55% Gasolines and 30% Distillates delivering a similar upgrade.

The following graph illustrates the relative vulnerable position for a refinery without any conversion units :

Graph: Typical Refinery margin for a **non conversion (Hydroskimming only)** refinery on Dubai crude oil:



Source: IEA refiners margins Oil market report July 2010

The most recent period (right hand side) shows a loss of over 2 USD/barrel for this simple refinery configuration.

It is evident from this assessment that the upgrading value from Visbreaking or any other upgrading is vital for long term profitability.

Further Visbreaker yield improvement should be studied by ERL. In this assessment the main parameters such as furnace temperature and residence time were observed as low degree of severity to moderate and it is recommended to test the unit at somewhat more severe conditions.

Basis test runs done on other similar units revealed the following result:

- Current ERL Visbreaker distillate yield on
- 100% Atmos Resid; (2007-2008 data): 16.5%
- Expected ERL Visbraeker distillate yield at higher temperatures on
- Atmos and Vacuum Resid from Kuwait crude**: 21.9%
- (after viscosity blending to correct to 250-300 cst for Visbr.Tar.)

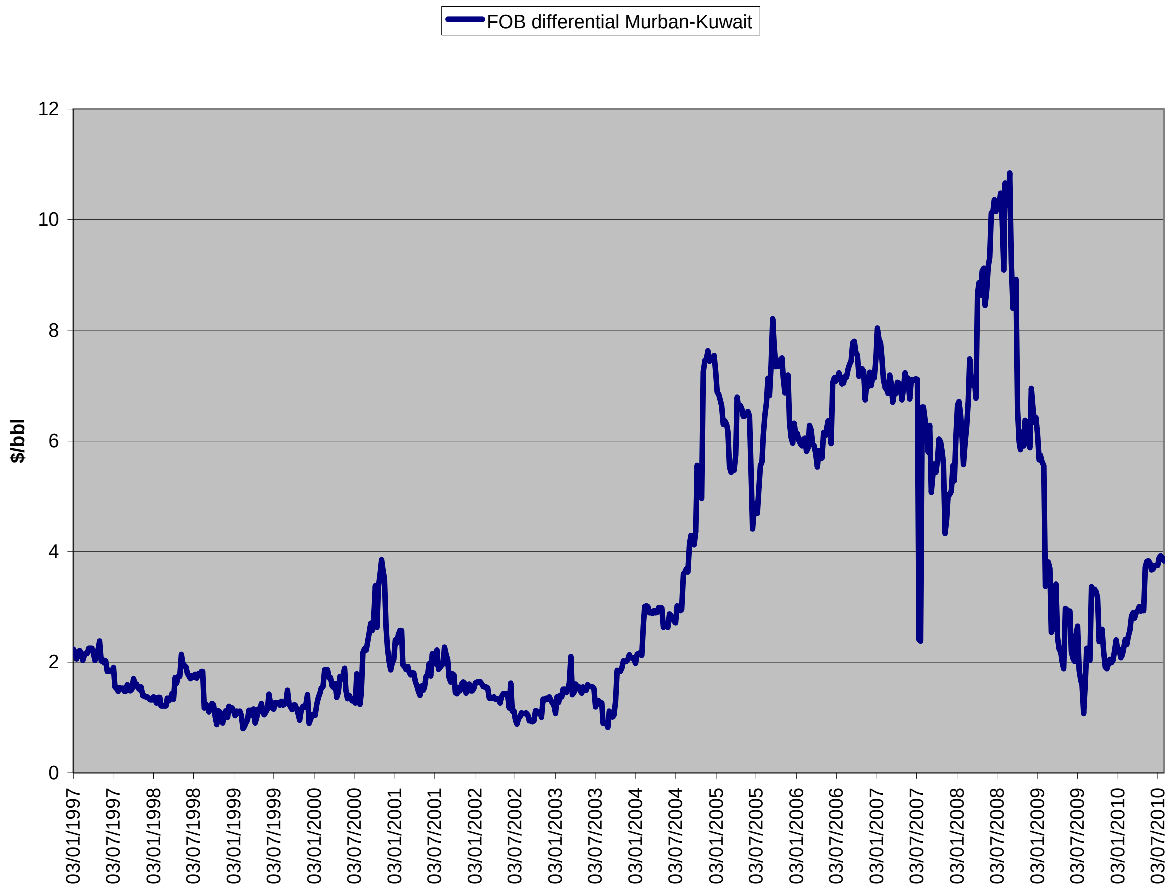
** See analysis in chapter on ERL Visbreaker Unit.

ERL 's Visbreaker capacity of 522000 ton/year feedstock, assuming all residual oil is processed in the Visbreaker, than with this change in operation conditions would generate an extra 28000 ton Distillate per year instead of Fuel Oil. This increase is approx 8% of current Diesel production and would improve the refiners margin by 0.60 USD per barrel crude oil.

Since circumstances are different for each Visbreaker/ Thermal cracking operation these results are not guaranteed. It only addresses the need to do tests with the designer /manufacturer of the unit to look at the conversion and apply more severe conditions with the aim to generate more distillate.

5.3 Assessment for Crude oil choice optimization at ERL.

A (FOB) price comparison between a light crude oil such as Murban (39.6 API) and a moderate heavy crude like Kuwait Blend (30.5 API) gives a purchase cost difference over the past 5 years of on average 6 USD/barrel.



In ERL case if it would have run 15000 barrel/day Kuwait crude instead of 15000 barrel/day Murban crude, the cost would have been 33 million USD per year lower.

The ERL product value would of course be lower as well as Kuwait crude contains more Residual Fuel Oil than Murban crude but product value would not have been lower by 33 mln USD , with the help of a higher severity operated Visbreaker.

Typical crude oil yield, cost and revenues are in most refineries compared on a weekly or monthly basis for a range of crude oils that can be considered as candidate for that refinery. Linear modelling like Aspen's Pimms, and Bonner and Moore RPMS simulation will rank the crude oils basis their optimised refiners margin using all available synergy.

For ERL to make such a comparison would probably generate an optimal crude oil slate somewhat different from the current 3 main crude oil slate, but one where refiners margins are maximised while producing those products that are demanded and priced locally and /or internationally at realistic market price levels..

Most likely it will also reveal that other crudes beside Arab light and Murban should be considered. For Bangladesh and BPC this may also mean a step into more unknown areas like active trading on international oil markets and to obtain shorter term crude oil contracts, and receive support from a various banks for the crude oil purchase from different suppliers and the aspects of financing.

Major oil producers and companies have over the past 10 years have sold an increasing number of refineries which are purchased, upgraded with conversion and operated both for domestic as well as international markets by professional trading organisations like Vitol, Glencore, Petroplus, Trafigura, Valero, Tosco, Itochu . These organisations operate as merchant refiners and collect the refiner's margins created by flexibilities in crude oil acquisition.

Though linear modelling analysis for ERL is complex and is beyond the purpose of this study, as a rule one may expect improvements in the mode of operation, due to crude and refined product optimisation of 2-4 usd/barrel for an average 100.000 barrel sized coastal refinery in Singapore, Middle East, Europe or USA Gulf Coast.

Summary for the refinery trading and optimisation:

- ERL technically can run a multitude of different crudes as a crude mixture and should not be restricted by Arab Light and Murban alone for technical reasons.
- Arab Light and Murban are relatively expensive crude oils. Prices for 10 API crude oil quality differences such as Kuwait Blend and Murban have been 6 USD/barrel recently. (45 USD/ton),
- Professional trading organisations with refining assets make these margin optimisations their business.
- The economic advantages of a different crude oil slate are usually quite substantial in the range of 2-4 USD/barrel.
- The availability of heavier crudes is growing (Africa, Mid East, Former Soviet Union countries, Caspian region).
- Variation in operating conditions in the existing ERL configuration can improve the distillate yield by conversion from Residual Fuel Oil to Distillates and apply a higher severity for gasoline octane.

6. ASSESSMENT OF ERL AND BPC IN RELATION TO PRIVATE ENTERPRISES REFINERY ACTIVITIES

6.1 Introduction

In Bangladesh only BPC is entrusted by the law to sell petroleum products to end users and industrial customers. Private enterprises have been allowed to do business in LPG, Bitumen and Lubricants.

To question the apparent restrictions to limit private enterprise only to these three ‘speciality’ products is not the purpose of this assessment, but almost all countries do allow private enterprise and State companies to be involved in the petroleum product refining and marketing and work together in competitive petroleum refining market.

Bangladesh so far has relied more on governmental control via BPC and other majority state owned companies for its refining and marketing than on the private sector. However there does not seem to be an Energy pricing policy or any developed views on the free market participation except in the discussion paper 2004 National Energy Policy document.

Assessment of a countrywide satisfactory basis for petroleum product operations from both a commercial and supply security viewpoint can benefit from participation of all parties because:

- Competition will lead to lowest prices and is beneficial for end consumers.
- Investment in petroleum refining (and marketing) is capital intensive, and is far easier to finance with private sector money beside state companies arrangements in a BB- rated country.
- Sensitivity to oil market changes is reality and encourages margin capture and participation by more interested parties than state owned oil companies alone.
- Competition forces all participants to be efficient and to adapt immediately to changing market circumstances.

The volumes traded by private companies are very small compared to BPC sales of 3.9 million tons per year:

Private company activity (estimated) in 2009 imports, handling and sales of

- LPG: 65.000 ton/year, all for bottling and household destination;
- Bitumen: 100.000 ton/year, mainly road bitumen
- Lubricants; 45.000 ton/year, both finished grads and base oils.
- Fuel Oil 100.000 ton/year KPCL Power station supply

So far Private companies are not allowed to construct or operate refineries and only moderate investment by the private sector in storage and handling facilities have taken place.

This restriction and the potential private interest has to be given reconsideration and will be important for the recommendation phase of the study in particular as financing a refinery construction project is complex and involves very large capital requirements.

6.2 Other private company views on refining activity.

In the draft National Energy Policy document (May 2004) there are references to opening refining activities outside BPC involvement.

- Encourage involvement of private sector in the petroleum industry.
- Private sector will be free to set up new refineries, however still with approval from Governmental institutions.
- The local pricing formulas leading to refinery product consumer prices will be based on import parity.
- Refineries will be free to sell their products to any marketing company or sell directly ex refinery gate.
- Private sector is encouraged to invest in refinery infrastructure; terminals, pipelines.

CHAPTER 4 : DUE DILIGENCE OF ERL PROCESS UNITS AND FACILITIES

This part of the assessment is the observation of and judgement on the technical operation and the process units. It is a brief and certainly no detailed description how the units are designed and configured in the current operation and some observations and remarks are made.

This due diligence forms the basis of all other assessments of the ERL refining operation in Bangladesh.

1. CRUDE DISTILLATION UNIT OR ATMOSPHERIC DISTILLATION UNIT

1.1 History

The ERL Crude unit is rated for approximately 33000 Barrel per day of fresh crude feed. Over the past years the crude oil diet has been fairly constant; 48% Arabian Light, 43% Murban, and 9% local Bangladesh produced Nat Gas Condensates (NGC). The original unit was constructed in 1967. The main distillation column (C-1101) was replaced in 1999 to this current capacity with a thorough overhaul. The column has valve trays with liftable caps, an installed packed bed in the Heavy Gasoil draw off section, which greatly improves the quality of the fractionation process.

The original unit is designed by Technip, who was later awarded a contract for Debottlenecking study of CDU in 1982. As a part of this study, TECHNIP carried out test runs for 24hrs each on Arab Light and Murban crude in Jan 1983. During each test run , CDU was operated at it's design capacity (about 173 Mt/hr for Murban and 190 MT/hr for ALC).

At the time Technip made recommendations which have been implemented by ERL:

1. During the Natural Gas feed burner connection to the Furnace, earlier burners were replaced by improved burners having flexibility to run on fuel oil and gas.

2. All tubes of radiation chambers of the Furnace (H1101) were replaced by alloysteel tubes (P-7) in 1981-1982, resulting in the much higher oxidation temperature of the tube materials. Also the furnace shell, convection zone tubing and chimney were replaced. As such, there is no limitation to raise the furnace outlet temperature above the coking initiation temperature (around 370 degr C)

3. 2" Steam valve was installed on the light Kerosene stripper replacing the earlier 1.5 inch valve.

4. Recommended lines have been replaced with recommended larger pipes.

5. A washzone (packed bed) has been installed in the bottom section of the C-1101 main fractionator column for improving the colour of Gas Oil.

1.2 Assessment Observations and Conclusions

1. The crude unit is a relative modern unit following its replacement in 1999, and major modifications to the furnace in 1982.
2. It is a relative small sized unit compared with most other refineries and has less benefit from economics of scale, energy use per ton, heat transfers, and overall losses per ton.
3. The overall energy efficiency as such is moderate to good, with proper use of exchangers, use of preflash and short transfer lines.
4. Some refinery gasses may be better controlled, utilised and preferably rerouted to the furnaces whilst saving on Nat Gas purchase and Liquid Fuel oil use.
5. The heat and pressure balance in the main fractionator tower is good and leaves some room to increase the throughput or add more lighter crudes into the feed. (Nat gas Condensate, see comment ERL Diesel hydrotreater chapter)
6. Maintenance is carried out routinely and there is a planned periodic overhaul. The state of all visually inspected parts of the crude unit (and the whole refinery) is excellent.
7. There is no acid resistant metallurgy in crude fractionation and transfer lines to allow running of higher than 0.5 TAN acidity crude oils.

1.3 Process flow description

The fresh crude feed is delivered from the crude charge pumps located in the process units area. The incoming cold crude feed is preheated in a series of shell and tube exchangers, the preheat train. Crude oil feed first picks up heat from the stripping units fractionated oil product rundown stream, then from exchange against the main crude column pumparound streams. Additional heat is then recovered from the Kerosene and Light and Heavy Gas Oil (LGO, HGO) product streams.

The preheated crude oil is warmed up to approx 135-155 degrees C. The crude is mixed with 2-3 % fresh water (from drum B1113) and fed to the Desalter Units (B-1111 and B-1112) for removal of the in crude oil present natural salts and other contaminants and impurities.

In the desalter the crude oil hydrocarbons and free water phase, but containing salts are separated chemically with demulsifiers and electrostatically with a 10 KV current. The water is drawn off for further treatment to the nearby API separators. There is no sour water stripping unit to purify this process water. The dry and cleaned crude from the desalter enters the Preflash fractionating column (B-1101).

The configuration of the crude preheat train has been set to maximize the heat recovery and hence energy efficiency of the overall facilities. ERL 's crude unit does use the exchangers for preheating in an efficient manner, however due to the Units location no other heat streams from neighboring high temperature surplus units, like the Visbreaker, are used in the preheating of the crude oil.

The Preflash fractionation column (B-1101) has no distillation trays and facilitates the first separation of the gaseous light ends and Light Virgin Naphtha from the heavier components of the crude oil.

Basis ERL current crude oil diet the preflash distillation generates an overall volume of 20-25% light ends that does not require further heating in the Crude oil units main furnace and thereby greatly improves the overall energy use efficiency . The flashed vapors from the preflash column are directly fed into the crude oil unit's main distillation tower (C-1101) in the upper section of the main fractionation column. Light ends vapors from the overhead preflash are then all fed forward onto a tray in the upper section of the main column.

The flashed vapours from the preflash column could be considered to be rerouted to the stabilizer (C-1103) to decrease the volumes and pressure in the crude unit column overhead section, allowing a higher throughput rate and/or increased intake of very light crudes such as the gas condensates.

The crude from the bottoms flow from the preflash column is led via booster pump (p-1102) into the second section of the preheat train, where the crude gains more heat from residue streams through contact in exchangers 1109 A and B and reaches a temperature of 200-220 degr C. The crude oil is then fed into the main Crude oil charge heater (H-1101 AB) and temperature is raised to approx. 375 degr C.

Furnace H-1101 is build as two separate fire boxes; radiation zones, each with high temperature absorbing steel tubing (installed after the Technip tests in 1982), and share one convection section and chimney stack for the superheated (to maximum 500 ºC) gases. A light gasoil pumparound is used to maintain the temperature gradient across the column, exchanges heat with the crude oil feed and is partly use to heat the reboiler of C-1104. Furthermore there is a Heavy gasoil stream used as reflux for the bottom of the fractionator.

The configuration of the crude preheat train is designed to maximize the heat recovery and energy efficiency of the unit. ERL's crude unit does use the exchangers for preheating in an efficient and effective manner.

Due to its location, no other hot streams from adjacent units like the Visbreaker are utilized for the preheating.

Currently ERL furnace outlet temperature is 367 ºC, which is within the normal range but on the low side. There seems room for increased overflash inside the main distillation column, necessary for good fractionation and for an 3-5 % increase in atmospheric distillate or heavy gasoil yield which would probably benefit the overall performance by a 10 º C furnace outlet increase to 375-380º C.

The furnace efficiency can only be established by measuring the excess air and temperature of the burned off gasses in the convection zone of the furnace. Preliminary data supplied by ERL suggest a 6.5-7% excess air and 430 º C flue gas temperature. On basis of these data a refinery furnace efficiency rating of 78% should be possible.

The furnace is dual fired with Refinery Gas or Natural Gas and liquid Fuel oil. In this main column the crude oil is separated into it's primary constituent products of overheads Liquid Petroleum Gas, Naphtha, Kerosene, LGO, HGO and crude tower bottoms (Reduced Crude). The overhead vapour; light ends and Naphtha from the tower are condensed and cooled to approx 45 degr C through Fin fans (EM- 1123 A-F) and water cooled via exchanger blocks

E-1110 A and B, and then routed to the overhead Reflux drum (B-1102). Note that cooling is more difficult at ERL than for a colder climate based refinery.

Inside the main fractionation or distillation tower (C-1101), the down flowing reflux liquid provides main tower tray cooling and partial condensation of the up flowing vapors, thereby increasing the efficiency of the distillation. The more reflux that is provided, the better is the tower's separation of the lower boiling from the higher boiling components of the feed. A balance of heating with a reboiler at the bottom of a column and cooling by condensed reflux at the top of the column maintains a temperature gradient (or gradual temperature difference) along the height of the column to provide good conditions for fractionating the feed mixture.

ERL's main fractionation tower has 33 trays and uses a reflux ratio of approx 1.8-2.1 against 1. (2.1 is max) . Part of the liquids hydrocarbons from Reflux drum B-1102 is partly rerouted back into the main distillation unit for atmospheric fractionating cooling purposes and partly send onto the Naphtha stabilization and splitter section for further processing. The reflux ratio is the ratio of the amount of hydrocarbon moles returned as refluxed liquid to the fractionating column and the amount of hydrocarbon moles routed as final product rundown, both per same unit of time. ERL's reflux operation is somewhat low but otherwise in line with normal refining practices.

The reflux drum releases at the top the methane and ethane, both considered to be refinery gas which can and should be used as burner fuel in the main crude units furnace or other nearby unit furnaces. In ERL case the majority of these gasses are used for as fuel in furnaces and some of it is flared.

The prime objectives of the Stabilization column C1103 are to stabilize light straight run naphtha and recover saleable LPG components from light hydrocarbon streams drawn from the reflux drum. In most refineries it is quite common is to see a stabilizer plant to effectively consist of three distillation towers interlinked in series; a de-ethaniser, a de-propaniser and a de-butanizer column.

ERL has no need for splitting and purification of propane and butane and therefore there is just a single de-ethanizer stabilization column (C-1103) where at the top of the column Propane and Butane are combined as one stream together with any of the remaining Methane and Ethane's. All gas components enter the (De-ethanizer) reflux drum (B-1103) together with any unstabilized light naphtha feedstocks. From the top of the drum the methane and ethane is drawn off and used preferably as burner fuel in the main furnace for heating the crude oil. The surge drum has a water boot to allow for withdrawal of any free water that settles out. From the reflux drum the liquids are pumped forward as a reflux back to the stabilizer column for cooling of the top section of the stabilizer and to obtain a proper split between LPG, naphtha and the lower boiling refinery gases. The majority of the Gas stream from B1103 is therefore LPG.

The off- gas form the primary source of fuel gas for the furnaces.

The now de-ethanised and free of water LPG is routed via a simple nearby LPG Merox unit (24000 ton/year capacity) for sulphur polishing and from there to the two LPG storage facilities or Spheres (1200 cbm capacity each) for further distribution to the LPG bottling/ filling plant.

The bottoms product from the Stabilizer (C-1103), called Full Range Naphtha flows under a pressure differential into the Naphtha Splitter (C-1104).

The Splitter is entirely dedicated to the separation of any still remaining gases in the Full Range Naphtha (FRN) and to recover the Pentanes C5 and Hexanes C6, together called the Light Naphtha and usually used as feedstock for Ethylene cracking units and Isomerisation and solvents units.

The Naphtha Splitter tower (C-1104) is a 20-tray fractionation column, which separates the FRN into a Light Naphtha (LSR) and a Heavy Naphtha (HSR) product. Light naphtha from the splitter tower overheads is condensed in an air fin fan cooler into the overhead reflux drum (B-1104). From this overhead drum LSR is provided as reflux to the splitter tower or routed to the light naphtha storage tanks. Un-condensed vapors are send to the Fuel Gas System and are not thus recovered by rerouting back into the splitter.

The splitter tower bottoms is a Heavy Naphtha and forms the feed to the Naphtha Hydrotreater section and subsequently will become the Catalytic Reformer feedstock.

The Naphtha splitter fractionation tower bottoms are re-boiled by an exchanger circuit which is heated by the pump around flow from the main distillation unit to provide the desired reheating duty to effect the proper separation of the light and heavy naphtha.

For ERL the final boiling cut point of the Heavy Naphtha is kept low (145-155 degr C) in order to maximize the production of (household use) Kerosine. An important side effect is the possible occurrence of unacceptable low flashpoints and smoke point. Smoke point control is essential for the production of Jet A1 Aviation fuel (DERD 2494 or Defstan 91) which international specification cannot be met without strict operating parameters, and Jet A1 fuel is only produced by ERL on a demand basis.

Jet fuel can be produced at ERL, but this would result in a much lower (estimated 6% less) volume of Jet Fuel type Kerosine (with cutpoints approx 180 C-235 C) than it is now for current household Kerosine SKO grades 1 and 2 production. (with cutpoints approx 140 C-280 C). If Jet fuel is produced then the lower boiling portion would then be produced almost entirely as Heavy Naphtha for which there is no demand as such, nor can it be used as Platformer feedstock with the small ERL reforming capacity already being filled up entirely.

The Kerosene grades SKO 1 and 2, Light Gasoil (LGO) and Heavy Gasoil (HGO) fractionation products are pulled as side-streams from the crude tower and steam stripped in their respective side-stripper columns. (Note: the installed four side stripper vessels are constructed inside a single tower (C-1102) placed adjacent to the main fractionation column. C-1101).

Kerosene 1 and 2 and LGO draws from the main fractionation column are mixed with refluxed Kero and LGO returning from their respective top of the stripper to a tray just above their lower cutpoint level. The remaining Kerosene and LGO products from the strippers are routed to storage for final product rundown after heat exchange against incoming crude oil feed in the preheat train. ERL today has no Hydrotreater or Hydrodesulphuriser available for removal of sulphur in Diesel components since sulphur content in Diesel is not regulated nor does it need hydrogenation or polishing of Kero as all Jet Fuel is imported instead.

The only available very small distillate hydrotreater was rebuild some time ago into a vacuum gasoil fed Mild Hydrocracker but without the provisions for required pressure increase and is currently shutdown. Therefore the quality of all distillate products from the C-1102 stripping tower is determined solely by the parameters set in the reflux from strippers and of course draw off trays in the main column C-1101. To now there is apparently no need of any additional sulphur removal equipment, while allowing the desired product specifications to be maintained in this circumstance by primary distillation only.

The HGO product from its individual side-stripper, is routed via the preheat exchanger for heat recovery to product rundown and diesel oil blending.

Small steam valves are added to improve the fractionation in each of the four strippers.

The main fractionator bottoms flow of ‘reduced crude oil’ (RCO) is routed for the bulk of the output directly to the Visbreaker unit for viscosity reduction / mild thermal cracking to match the furnace oil viscosity specifications. Alternatively, only for Arab Light crude oil it can also be routed directly as hot feed to the Vacuum column for the production of Vacuum Gasoil and Asphalts in the Bitumen blowing unit.

The residue or reduced crude is not passed back into the stripping section via a re-boiler to recover the maximum of distillates under atmospheric conditions. Most crude oil distillation/fractionation towers have a re-boiler as it not only optimizes the distillation yield, but also helps preventing the tower stripping bottom from fouling and prevents unwanted cracking. Usually a re-boiler can be regarded as heat-exchangers with a minor furnace that are designed to transfer enough energy back into the reduced crude to bring the liquid at the bottom of the column back to boiling point.

The ERL crude distillation unit has a steam injection system in the stripping section bottom of the main fractionation column. In order to strip all light hydrocarbons from the reduced crude or atmospheric residue fraction properly, the bottom section of the column is equipped with a set of 4 to 6 stripping trays, which are operated by injecting some stripping steam (1 - 3% on bottom product) into the bottom of the column. The steam reduces the partial pressure of the hydrocarbons and thus lowers the required vaporization temperature and more remaining light distillate can be recovered.

Summary of current operating process parameters are given in the table-1 below

ATM Distillation Column (C-1101)	Stabilization Column (C-1103)	Redistallation Column (C-1104)
Temperatures Feed to C-1101 : 365 – 367 Top of C-1101 : 127-134 Bottom of C 1101 : 360 – 362 C Internal Reflux :135 – 140 C to C-1101 Reflux to C 1101 : 40 – 42 C Stack Bottom of Furnace(1101) : 500 C (Max) Draw off Temp. K 1 : 180 - 182 C K2 : 200 – 208 C LGO : 312 – 320 C HAO : 348 – 352 C Pressure Top of the col C-1101: 2-2.5 barg Bottom of C-1101 :2.2 – 2.7 barg Reflux drum B-1102 :0.75-95 barg Flash Tower B-1101:3.0-3.5 barg Bottom stream : 4.2 – 4.6 barg	Temperatures Feed to C-1103 :130-133 C Top of C 1103 : 70-72 C Bottom of C-1103 :178-182 C Reflux to C-1103: 40-42 C Pressures Top of C-1103: 9.2 to 9.4 barg Bottom of C-1103: 9.8-9.9 barg Reflux balloon(B-1103) : 9.0 barg	Temperatures Feed to C-1104:85-88 C Top of C-1104:82-85 C Bottom of -1104:130-132 C Pressures Top of C-1104 : 0.3 barg Bottom of C-1104 :0.7 barg Reflux Baloon(B-1104): 0.3-0.7 barg

Actual realized yields on the Crude Oil Distillation Unit during recent runs:

Crude Distillation Unit (CDU)

Product	Yield % weight	
	ALC	Murban
Gas + Loss	1.72	1.73
LPG	0.6	0.92
Light Gasoline	6.97	7.68
Heavy Gasoline	3.9	8.51
Light Kerosene	9.18	10.75

Heavy Kerosene	12.3	13.06
Light Gas Oil	17.34	19.33
Heavy Gas Oil (372 deg C cutpoint)	6.09	7.9
Reduced Crude Oil	42.07	30.01

These yields are a reflection of a good performing distillation operation. Note the relative small volume of Heavy Naphtha and corresponding large volumes of (here called; light) Kerosines.

2. ERL Vacuum Unit / Asphalt Plant

2.1 History

The ERL vacuum unit is a unit operated to generally prepare feed to produce road paving and some roofing grade asphalts from the predominantly Arabian Light crude oils and possibly other bitumen qualified feedstock like Kuwait crude oil and Iranian Light crude oil to the refinery. The vacuum unit and associated bitumen blowing plant were originally constructed in 1980, and have been turned around several times. (current rated capacity is approx 4000 Barrel per day maximum charge).

ERL declares the unit intake to be 200.000 ton per year of reduced crude from the Crude distillation unit, and for the associated Bitumen unit 70.000 tons per year capacity. This means that the capacities of Vacuum and Bitumen plant are not entirely matched.

The main vacuum fractionation tower was most recently turned around in 1999 together with the Crude Unit. The unit operates continuously to match the asphalt demand requirements of the country. Demand for bitumen is much higher than ERL production capacity.

2.2 Assessment Observations and Conclusions

8. The Vacuum Unit is a relative modern unit from 1980 and completely turned around in 1999 .
9. It is a relative small sized unit at 4000 barrel/day compared to the atmospheric residue output (RCO) from the crude oil distillation unit at approx 14000 barrel/day and entirely designed to produce Bitumen in the nearby Bitumen blower unit.
10. TheVacuum Unit furnace is relatively large, reflecting the need to reheat the RCO to 380 degr C.
11. The Vacuum fractionation column is relative tall and narrow, which is designed for maximum volatility to obtain a good separation of Bitumen and Vacuum Gasoil.
12. Vacuum Gasoils are blended in Diesel and Fuel Oil. There is no lubricants process facility that would use Vacuum gasoil.

2.3 General Process Description

The Vacuum unit feed is taken as a portion of the crude unit Atmospheric tower bottoms for Arab Light crude only, with the balance of these bottoms, the majority, being routed to the Visbreaker section of the processing facilities. The feed is taken from the crude unit bottom, passes through heat exchangers and flows then into the vacuum unit charge heater or feed is drawn from tank. The single furnace is fired by refinery gas or natural gas or both as a mix.

In modern refineries high pressure steam is usually injected into the feed line to the furnace to suppress coking and maintain coil velocities. ERL does not require this steam injection as coking is avoided because of the sufficient reduction of the feed temperature in the transfer from Crude Distillation unit to the Vacuum Unit. There is then the need to reheat the feed back to operating conditions (380-390 degrees C). The ERL vacuum tower also misses vacuum gasoil side strippers as the quality and cut points of the Vacuum gasoil do have limited value in the overall operation. There is no hydro cracking or catalytic cracking or lubricant oil plant for which Vacuum Gasoil is the obvious feedstock.

The objective here is to produce bitumen and the light vacuum gasoil (LVGO) is a byproduct and is used as blending component in Diesel. Despite the high sulphur, high pour point and cloud point of Vacuum Gasoil, a significant volume can be blended into the Diesel pool as Bangladesh climate does not require these cold property limits in the diesel specification. Heavy Vacuum Gasoil (HVGO) was the designated feedstock for the now shut Mild Hydrocracking Unit, but now goes into the fuel oil pool.

The design of the Vacuum unit reflects this objective. A modern Vacuum Unit is characterized by a relatively short but wide diameter column which allows maximum retrieval of deep vacuum distilled distillates. ERL's vacuum tower is build as a small capacity unit relative to the Crude unit, with a tall but small diameter column, typically designed for a proper split between bituminous residue and Vacuum distillates. The small diameter of the unit will also limit the potential for higher throughputs and unlikely to be able to realize a deep vacuum of 10 to 20 mm Hg inside all sections of the fractionation column. Medium pressure steam is superheated in the charge furnace convection section for use as stripping steam in the main vacuum distillation column as well as in steam injection.

The column has some packed trays instead of all valves which will improve the distillation, reduce pressure drop and compensates for the missing side strippers.

The Vacuum itself on the main vacuum fractionation column is generated by a conventional (multiple-stage) steam ejector system. Each stage contains steam ejectors with motive force derived from medium pressure steam. The first stage ejectors draw the column overhead vapors into a pre-condenser exchanger, where they are partially condensed against cooling water. Condensates from the pre condenser flow down into the overhead condenser vessel. Residual vapors from the barometric condenser vessel are drawn by the next stage ejectors and exhausted to atmosphere. A circulating stream of sour condensed water, is drawn from the overheads condenser vessel, is further cooled against cooling water and enters the top of the barometric condenser vessel to suppress vapor release. The barometric condenser vessel also drains into the overheads condenser vessel. In the overheads condenser vessel small quantities of hydrocarbons are collected as a slop oil and routed back to storage. Sour waters from the steam ejectors condensates are pumped to the API separator /treatment area. Residual off-gas vapor from the overhead condenser vessel is routed to the flare or separate incineration furnace.

Vacuum distillation increases the relative volatility of the two key components inside the Residual Oil from the crude unit; Vacuum Gasoil and Vacuum Residue, which latter is the feedstock for the Bitumen blowing unit.

The higher the relative volatility, the more separable are the two components and this requires fewer stages in a distillation column in order to effect the same separation between the overhead and bottoms products. Lower pressures increase relative volatilities. The two product streams; Light and Heavy Vacuum Gas Oil are withdrawn from the main vacuum fractionation tower and flows through heat exchangers and water coolers to storage. The LVGO is preferably routed to diesel oil blending and the HVGO is routed to the fuel oil blending product rundown. The Light Vacuum Gas Oil stream is drawn from the upper section of the main vacuum tower and could be used as a pump around with exchanger cooling reflux for distillation control, however ERL does not need such quality control.

The main vacuum fractionation column bottoms are pumped to the nearby Bitumen blowing facility.

In general , the refinery bitumen production cannot meet Bangladesh road paving quality requirements by just straight run vacuum distillation alone. Most countries have formulated a variety of bitumen grades with often stringent quality specifications, depending on climate and intensity of road use. The specifications are mainly expressed as narrow ranges for penetration and softening point. These special grades are manufactured at ERL by blowing air through the hot liquid Vacuum Residue in the Air Blowing column (capacity 70.000 ton/year). By blowing, the asphaltenes in the vacuum residue are partially dehydrogenated (oxidised) and form larger chains of asphaltenic molecules via polymerisation and a condensation mechanism. Blowing will yield a harder and more brittle bitumen (lower penetration, higher softening point) The bitumen blowing process requires a dedicated feedstock quality. In ERL's case the residues from Arabian Light crude.

The blowing process is carried out continuously in the blowing column. The liquid level in the blowing column is kept constant by means of an internal draw-off pipe. This makes it possible to set the compressed air-to-feed ratio (and thus the product quality) by controlling both air supply and feed supply rate. The feed to the blowing unit (approximately 210 ^{0}C), enters the column just below the liquid level and flows downward in the column and then upward through the draw-off pipe. Air is blown through the molten mass (280-300 ^{0}C) via an air distributor in the bottom of the column. The bitumen and air flow are countercurrent, so that air, low in oxygen, meets the fresh feed first. This, together with the mixing effect of the air bubbles jetting through the molten mass, will minimize the temperature effects of the exothermic oxidation reactions: local overheating and cracking of bituminous material. At ERL this seems very well under control as there were no signs of fouling of the Bitumen unit at all. The blown bitumen is withdrawn continuously from the bottom of the blowing tower and pumped to heated storage through feed/product heat exchangers.

At the top of the tower any gasses and small liquid streams that have formed are drawn off and neutralized in a small incinerator furnace.

Summary of actual realized yields on intake of feedstock

ABP Unit

Product	Yield % weight
LVGO	25.10
HVGO	23.80
Bitumen	49.68
Loss	1.41

These yields are perfectly in line with what can be expected based on the Arab Light crude oil assay. Note that Murban crude is not a suitable crude oil to produce feedstocks for Lubricant oil and Bitumen.

3. ERL Catalytic Reformer Unit (Platformer)

3.1 History and general description

The Catalytic Reformer was built in 1967 as part of the original ERL refinery. It is of a semi regenerative type and uses a platinum based catalyst, hence the name Platformer.

All reactor vessels are filled with platinum type catalyst which remains static inside the reactors throughout the process. The reforming process requires a regeneration of that catalyst after a certain period due to the catalyst becoming less active and therefore less effective because of growing contamination during the process. The frequency of regeneration, the reconditioning of the catalyst activity, depends on the degree of severity of the conversion of paraffin chains into aromatics.

The ERL unit consists of a three step reactor phase each with its own furnace and a (separate) hydrotreatment phase which precedes the actual reforming process. The reformer, designed and build by IPF of France is still at its original design capacity of up to 1700 Barrel per day (70.000 ton per year) of the feed which is the heavy naphtha stream produced in the Crude (and Visbreaker) Unit. The unit is very small compared to the Crude Unit theoretical output of Reformer feed Naphtha (estimated at approx 3000-4000 barrel per day), and because of its limited design capacity of the reactor vessels, a major increase in production capability by debottlenecking the throughput flow, is unlikely to be effective and realistic.

ERL prefers to maximize the Kero fraction, and to cut a higher end boiling point light Naphtha fraction. This mode of operation reduces the available heavier Naphthas as potential feedstock which will still be more than sufficient to meet the maximum capacity of this Platformer.

Furthermore another potential Naphtha supply comes from the Visbreaker Unit rundown. Currently ERL routes this stream into storage for blending or for treatment in the Merox unit as a mixed stream with light visbreaker gasoil and even into the burner fuel pool for firing the furnaces. Visbreaker Naphtha is very unstable and should be considered as unsuitable for any blending in the Naphtha or into the gasoline pool. ERL however could consider to reroute this naphtha to the Platformer hydrotreater section which will remove smell and in general all the instabilities and improves the overall quality.

For convenience, the Catalytic Reformer Unit may be divided into four parts:

- 1. Feedstock Hydrotreater Section.
- 2. Reactor Section.
- 3. Recycle Gas Systems and Hydrogen handling Section.
- 4. Reformate Stabilizer Section.

3.2 Assessment Observations and Conclusions:

1. The Platformer is very small at 1700 barrel /day and not even in proportion to the estimate 3000 barrel day heavy naphtha feed output from the 33.000 barrel day Crude Unit.
2. Design is a semi regenerative catalytic Platformer, with 3 fixed bed reactors and a preparation naphtha feed hydrotreater.
3. Catalyst regeneration cycles are every 3 years, which is very long for the catalyst to stay active. Octane levels of the Platformate are 88-90 RON which is low compared to normal 98-100 RON.
4. Combination of higher severity, if allowed, and shorter regeneration periods will allow ERL to produce the 95 RON unleaded gasoline, now entirely purchased, with good economics to support.
5. Net hydrogen production is used as refinery gas and not utilised as Distillate Hydrodesulphurisation hydrogen supply.

3.3 Process flow description

A summary of the process functions of these various parts is as follows:

3.3.1 Naphtha Hydrotreater

The heavy naphtha from the Crude Unit is processed in the Naphtha Hydrotreater Unit. This heavy naphtha is produced as a bottoms stream from the Naphtha Splitter Unit which is part of the Crude Unit. The platinum catalyst used in the Platforming process is delicate and will lose its effectiveness and reaction capability when contaminated with impurities. Therefore all feed to the Platformer must have sulfur, metals and other contaminants removed so that any remains are only in the very low ppm levels.

Hydrotreating of heavy naphtha from ERL chosen crude oils like high sulphur Arab light crudes and medium sulphur Murban is a must to prevent acceleration of catalyst contamination with higher sulphur naphtha.

The naphtha from the Crude Distillation unit Naphtha Splitter bottoms is pumped and mixed with Hydrogen rich gas (from the Platformer High Pressure Separator) and are preheated in heat exchangers with the Reactor's rundown effluent. Hydrotreating is an exothermic reaction, where heat is produced from the reactants.

The hydrogen + naphtha mixture reactor inlet temperature is raised in the hydrotreater furnace (F-1201) to a temperature required; for most units approx 350 degr C, and at ERL currently around 325 degr C. The mixture flows to the reactor which is filled with a cobalt or nickel molybdenium catalyst where the hydrotreating reactions take place. (mainly sulphur, nitrogen and metals removal).

Because of its undesired high olefin content, the Visbreaker heavier naphtha may well be combined with the Heavy Naphtha from the Crude Unit Naphtha splitter. More unstable Visbreaker naphtha is preferably first compressed by the Hydrotreater Compressor together with the Platformers hydrogen rich gas to saturate the olefins, and then passed downward with the virgin Naphtha from the crude unit through the Platformer separator's hydrogen rich gas and then onto the catalyst in the Naphtha Hydrotreater Reactor for removal of impurities.

The hydrotreated treated naphtha runs down into the Naphtha Hydrotreater Separator where the gasses are removed and dewatered, and then countercurrently contacted with Platformer Separator Off-Gas in the Stripper-Absorber (C-1201) to strip traces of hydrogen sulfide, ammonia, and hydrogen chloride from the treated naphtha to make this treated naphtha suitable as Platformer charge. The stripped hydrogen sulfide, ammonia and hydrogen chloride remain in the hydrogen-rich gas stream through the Naphtha Hydrotreatment reaction stages, and are finally separated in the strippers reflux overhead drum (B-1202). The reflux drum separates the refinery gasses and liquids are rerouted back in the top of the stripper-absorber column.

The Stripper-Absorber serves a two-fold purpose: to strip the undesirable contaminants from the naphtha, and in addition, the naphtha absorbs light hydrocarbons from the Platformer Separator Off-Gas, thereby permitting return of these light hydrocarbons to the Platformer. The Naphtha Hydrotreater Stripper bottoms are re-boiled in furnace F-1202 and rerouted back into the stripper to improve the final removal of all light gasses including any LPG and refinery gas. ERL could add the Visbreaker Naphtha to the overall Naphtha stream to maximize the Platformer feed stream.

3.3.2 Reactor Section

The Reformer Reactor Section consists principally of: Feed Heater F-1205; Feed (Inter) heaters F-1203, and F -1204; Reactors R-1202, R-1204 , R-1203, Product Separator B-1201 and heat exchangers and the Reformate Stabiliser or Stripper Absorber with reflux overhead condenser and a bottom stream reboiler.

In the Reactor Section, hydrogen-rich Recycle Gas and the hydrotreated naphtha charge are brought to reaction temperature and pressure of 488 degr C and 435 psig (approx 30 bar), respectively, and passed over the platinum catalyst in the three Reactors. The reactions occur in each of the Reactors, and after the third reactor phase the cooled platformate effluent is discharged into Product Separator (D-1201). The gas fraction which separates in the Product Separator consists principally of the hydrogen produced during the reactions in the Reactors, along with the Recycle Gas. This gas from the Product Separator passes to the suction side of the Recycle Gas Compressor immediately behind the Separator. The liquid fraction in the Product Separator consists of the reformed naphtha (reformate) and light hydrocarbons like LPG and some other olefinic and aromatic hydrocarbons produced during the reactions in the Reactors. This Separator liquid is discharged to the Platformer Stabilizer Section , which works almost identical as the Stabilizer described in the Crude Unit. With the relative high temperature of around 500 degr C there is a water cooled exchanger to reduce the temperature of the flow into the stabilizer overhead reflux drum. The liquids are then rerouted back to the stabilizer as reflux.

3.3.3 Recycle Gas System and Hydrogen Storage Section

This Section consists principally of the Recycle Gas Compressor which takes all of the off-gas from the Product Separator and compresses it from the Product Separator pressure of about 310 psig to 435 psig (30 kg/cm2). Most of this gas joins, as Recycle Gas, with the Platformer naphtha charge. The excess, or net Reformer Separator Off-Gas consists of the hydrogen produced during the reactions in the Reactors, and is discharged to the Hydro treater Unit, and in the past to the Distillate Hydrotreater/Mild Hydrocracker, now shutdown. Therefore most of the excess Hydrogen is used as burner gas in the furnaces or alternatively some hydrogen could be stored in a dedicated vessel (cigar type) for future use.

3.3.4 Stabilizer Section

The Stabilizer Section consists of Stabilizer (C-1202) and associated pumps, heat exchangers, and vessels.

The Stabilizer receives the Separator liquid, and separates this liquid into reformate and light hydrocarbons by fractionation. The Stabilizer may be operated as a De-butanizing operation (separating C_4 and lighter hydrocarbons from the reformate), or could be operated to include and remove some of the C6 aromatics like Benzene from the Reformate.

The light hydrocarbons separated from the reformate pass from the Stabilizer Section as Stabilizer Off-Gas, while the stabilized reformate is send as rundown stream to storage. ERL apparently does not recover the (unsaturated) LPG that is a major part of the gas that is separated in the stabilizer and its condensor, but uses all gas as burner fuel gas in the furnaces. This needs further examination though.

The mass balance for the ERL Platformer./Hydrotreater is 85 % Platformate and 15% Gas+losses against 100% of Naphtha feedstock. This reformate recovery percentage compares well with other similar semi regenerative Platformer units in Europe and Asia, however it is the much lower octane of 88-89 RON which does not compare well. Also the ERL treatment of the 15 % mixture of LPG, Hydrogen and refinery gasses as a potential burner fuel after the partly used stream as recycle Gas should be reviewed for better recovery of the LPG from the Separator or from the Stabilizer.

Most refineries have replaced their semi regenerative reformers with more modern continuous regenerating Platformers, which allow a high octane of well over 103 RON, combined with moderate severity which improves reformate yields to 91-92% and no downtime for regeneration.

ERL has a semi-regenerative Platformer and is designed for moderate severity, in ERL case an operating pressure of approx 30-35 kg/cm2. As a result the catalyst regeneration cycle is well over one year and could be stretched to even 3-4 years, which is a very long operating period, compared to other more severely operated (50 kg/cm2) semiregenerative Platformers. The disadvantage is a relative low Octane of the Platformate of 88 to 89 RON, and does not allow ERL to produce the standard 95 RON unleaded gasolines. ERL may review the unit capabilities whether to increase operating pressure to 50 kg/cm2 to produce a higher octane such as a 98 RON grade that will make a finished 95 unleaded gasoline grade in a blend with some surplus light naphtha and even some butane. However higher operating severity will cause the regeneration stop periods to increase, as expected a 10-14 day catalyst regeneration stop every 7-9 months.

Economics may suggest the right operation for ERL given its current Reformer by comparing the lost regeneration days production against extra expenses to buy the currently purchased 95 gasoline with that of 88-90 octane gasoline which ERL produces now for its MS grade..

The evaluation is based on an increase in pressure to 50 kg/cm2 in the Reactors, with an operating temperature around 500 degr C. The expected Research Octane number (RON) will rise from current 88-90 RON at todays conditions at 30-35 kg /cm2 to an expected 98 or higher RON at higher severity.

Reformate output yield are expected to remain around 85-86% wt as higher severity pressure also improves the conversion of naphthenes into aromatics instead of forming propylene and butylene and refinery gasses. A 98 RON reformate can then be blended with light Naphtha and Butane (depending on volatily or Reed Vapour Pressure maximum specification) to produce a 95 unleaded Gasoline grade.

	Increase Platformer severity for unleaded 95 Current Reformate octane 88 Ron, unleaded 95 imported					
Platts Apagscan						
Fob Singapore	06/08/2010		mean			
			$/bbl	$/ton(calc)		
Gasoline 95 unleaded			86.78	722.88		
Gasoline 92 unleaded			85.14	715.18		
Naphtha			75.36	655.63		
freight Sing-Chittagong				11.00		
Calc Octane value 1 RON				2.57		
Calc differential value 95- 88 gasoline				17.97		
ERL Platformer 70000 ton/year	days	tons				
reformer octane benefit days	351	67392		28.97	$1,952,341.75	per year
regeneration cost						
Gasoline 88 lost, Naphtha export	14	2688		60.28	$162,020.45	per year
Net benefit					$1,790,321.29	per year

The above calculation is based on Singapore Platts values of 6 August 2010, and does not include the advantages of blending lower value light naphtha into 98 RON reformate. It is solely a comparison of ERL produced 95 unleaded gasoline less the cost of not producing 88 RON reformate for a 14 day regeneration period.

Of course the quality and integrity of the Unit under increased severity must be tested and approved by the designer. Also economics may change with changing Platts prices.

4. ERL Visbreaker Unit

4.1 History

The Visbreaker Unit was commissioned in 1994 with a capacity of approximately 522000 ton/year (9500 barrel per day) .as the major part of the Secondary Conversion Plant (SCP) project.

The project included also the redesign of the existing ERL Distillate Hydrotreater into a Mild Hydrocracker and a new Methane Steam Reforming Unit.

The Visbreaker is designed for processing of the Reduced Crude Oil (Atmospheric Long Residue) from the ERL Crude Distillation Unit. The primary aim is to increase the production of Distillates by moderate thermal cracking or visbreaking of that residue.

Atmospheric residue Visbreakers are rare, as most Visbreakers are designed to run on much heavier feeds from the Vacuum unit and are designed to reduce the high viscosity of the vacuum resid feed to commercial levels of 380 cst. In ERL case, there is mainly Atmospheric Resid as there is no large size Vacuum Unit to produce Vacuum Residue. The Atmospheric residue has a much lower viscosity and does not need a massive reduction in Viscosity if at all, so that thermal cracking results in more Visbreaker gasoil output.

4.2 Assessment Observations and Conclusions

1. The Visbreaker is ERL's only conversion unit, capable to convert approx 16 % of the residue into distillate.
2. The design is for 9500 barrel/day which is equivalent to 522000 ton/year.
3. The unit is modern, with good energy efficiencies and has potential for enlargement of the throughput capacity.
4. The Visbreaker produces unstable components like the Gasoil that should be treated within a hydrodesulphuriser.
5. The degree of severity is very mild, partly due to prevent flocculation and instabilities of the fuel oil.
6. The ideal feed for this unit would be Vacuum Residue instead of all Atmospheric residue based on testruns on similar units elsewhere.

4.3 Brief description of the Visbreaker Unit

4.3.1 Visbreaker Feed System

Atmospheric Residue Feed to the Visbreaker Heater (BA3001), is supplied by the Visbreaker charge pumps. The suction line of these pumps is connected to the bottom of the Atmospheric Crude Distillation Main Column and the Atmos residue intermediate storage tanks.

The feed enters the by KTI designed Furnace heater after passing through a feed surge drum to remove any water or gasses before reheating takes place.

The Visbreaker is very well designed for its heat exchanger efficiency.

Feed leaves the collection tank at approx 85 degr C, and temperature is raised through exchangers (against hot visbroken products from the fractionator and stabilizer) to 335° C before the furnace inlet, which is a very good heat exchange transfer.

Furnace outlet varies but is around 445 degrees C, with a backpressure from the feed pumps to 20 kg/cm2.

4.3.2 Visbreaker Heater and Transfer Line

The Visbreaker Heater (BA-3001) is a two cell heater designed by KTI to a heat combustion capability of 14.800 Kcal/hr or 17.2 MegaWatt/hr. It can fire natural gas and/or refinery fuel gas. The two cells have a common convection section, which in addition to the feed preheating exchanger, also has coils for superheating saturated steam.

Visbreaker unit feed in the furnace is controlled by flow ratio controllers.

Velocity in the heater tubes is controlled by injecting high pressure steam in the radiant section of the heater.

The heater is operated with an outlet pressure of 290 PSIG (20 kg/cm2), and the pressure is controlled by a control valve/restriction orifice combination in the transfer line.

Thermal cracking reactions are initiated in the heater tubes when the feed temperature reaches approximately 410 ^{o} C, and the feed is heated to a maximum outlet temperature of 445^{o} C.

The heater outlet temperature is controlled by regulating the amount of fuel being fired in each cell, and a separate temperature controller is provided for each cell.

In order to control the cracking reactions and minimize coking of the transfer line from furnace to the fractionator, the effluent temperature is kept to 425 C in the transfer line by a mixture of cooled visbreaker gas oil and Fuel Oil. .

4.3.3 Fractionation System

The fractionation system separates the cracked components/ effluent into a gas product, a naphtha product, a gas oil product, and a Fuel Oil product, and includes the following:

- A very tall and wide diameter fractionator containing 35 2-pass valve trays.
- Fractionator overhead condensing section comprised of an Air Cooler and overhead Condenser and Overhead/Reflux Accumulator. All gasses from the overhead condenser are rerouted back into the fractionator.
- Gas Oil Stripper, with an air cooler plus exchanger for the Visbreaker gasoil stream.

The Visbreaker heater effluent is fed into the flash zone of the fractionator somewhat below the tower midpoint.

The overhead temperature is maintained at approximately 150 ^{o} C by a temperature controller which resets the top reflux rate.

Overhead vapors from the Gasoil Stripper are cooled to 42 degr C in overhead condensers and the refinery gas is separated from the liquid product and rerouted to the burner tips of the furnace..

Visbreaker gas and liquid product from the fractionator and the Gasoil stripper are routed for further processing to the Separator /Absorber, where a portion of the condensed naphtha is returned from as top reflux to the Naphtha Stabiliser.

Visbreaker Fuel Oil; the fractionator bottom is stripped with 150 PSIG steam to remove the light ends and the stripped Fuel Oil at approximately 350°C is routed through Visbreaker Bottom Exchangers where it is cooled against fresh feed to the Visbreaker furnace.

The ERL Visbreaker is, as explained, required to run on atmospheric resid. This atmospheric or long resid still contains (for Arab light and Murban) more than 50 % Vacuum Gasoil which is paraffinic by nature.

The paraffins or saturated straight molecules are in general a poor feed for thermal cracking as they tend to form unsaturated components that will produce very unstable Visbreaker Gasoil, but also cause unstable heavier long chained aromatic hydrocarbons; asphalthenes. These molecules tend to attract each other and cause instability and flocculation (lumps) in the visbreaker fuel oil. Reduction in severity is the obvious answer to prevent flocculation or is the addition of highly aromatic components to the fuel oil to satify the instable unsaturated chains. ERL does not produce the high aromatic blending components so it will have to reduce severity in order for the fuel oil to remain stable.

Such low severity will limit the production of Visbreaker distillates and naphtha. Currently over 2007-2008 the Visbreaker yield on 100 % Atmospheric Resid was approx:

SCP Unit

Product	Yield % weight	
	ALC	Murban
Naphtha + Loss	2.00	1.80
Gas Oil	16.00	21.00
Residue	82.00	72.20

Corresponding test runs on similar qualities atmospheric residue and applied to thermal cracking operations are slightly different but results are similar as for the above ERL results.

Results on Visbreaker conversion improve dramatically If the feedtock is 100% Vacuum or Short Residue (with all Vacuum Gasoils removed). The Visbreaker cracking process with Vacuum Resid feedtock will not cause instability and will produce slightly less distillate and Naphtha but stable Fuel oil with somewhat higher viscosity that will need to be corrected with some Visbreaker gasoil or other low viscosity diluents.

The conversion yield on Short (=Vacuum) residue is almost identical as on Long residue, but there is the advantage from the uplift of the from the Vacuum Unit recovered Vacuum Gasoil instead of all being atmospheric residue. These are substantial gains with a yield of approx 50% Vac Gasoil from Long residue.

However this kind of operation is not relevant for ERL as there is not the required Vacuum Distillation capacity to operate in this way. Note that Vacuum Gasoil has a (varying but approximated) value of Gasoil *80% on the international markets or even better value if the Vacuum Gasoil is fed and cracked to good quality low sulphur Diesel in a Mild Hydrocracking unit.

Therefore Visbreaker (and Vacuum Unit) economics would have significantly improved if ERL could take all atmospheric Resid through a Larger Vacuum Distillation unit and either sell the Vacuum Gasoil to the international markets in Singapore, Japan and China, or process on the ERL refinery site in a Mild Hydrocracker. The Vacuum Residue is then a much more suitable feedstock than the current Long residue for a Visbreaker or Thermal Cracker .

4.3.4 Visbreaker potential for enlargement.

Both the furnace heater capacity, and the preheat exchangers system will permit a larger throughput. Also the Visbreaker fractionator with some (minor) modifications to reflux and stripping sections should allow higher than 522.000 ton/year throughput. A cautious estimate would suggest 20-30% more. Of course this is purely based on observed heater and fractionator capacity and the very moderate severity mode of operation.

5. ERL Diesel Hydrotreater Unit/ Mild Hydrocracking Unit

5.1 History

The original design of this unit is based on the Distillate feed consisting of Kerosene and in particular Diesel Oil fractions from the Crude Unit. The unit was commissioned together with the Crude Unit and Platformer in 1968. The Diesel hydrotreater unit is in function and purpose similar to the Naphtha hydrotreater, Unit as dieselhydrotreater had a capacity of approx. 75.000 ton/year (1600 barrel per day).

Typical operation conditions are a furnace outlet temperature to the reactor of 350-370 degrees C and reactor pressure between 30 and 50 kg/cm2 delivered by compressors at the inlet of distillate feed mixed with rich hydrogen gas (from the Platformer).

Its main purpose was to remove sulphur and secondary to improve color and hydrogenation to increase the Cetane Number from the Crude Units Main fractionator Gasoil.

However the unit was closed and mothballed in 1973.

In 1994 the unit was revamped into a Mild Hydrocracker (MHC) as part of the Secondary Conversion Project, with the aim to convert part of the Heavy Vacuum Gas Oil (HVGO) feed into low Sulphur Diesel. Parts of the unit like the charge heater and compressors were revamped to facilitate this new higher severity Mild Hydrocracking Process. Throughput capacity of 57000 ton per year.

Vacuum Gasoil needs approx 5-7% wt hydrogen per 100% feed to fully saturate the partly napthenic and aromatic vacuum gasoil feed structure into more paraffinic hydrocarbons.

Hydrocracking reduces also the gravity of the hydrocarbon feedstock, it removes impurities like sulphur, metals, nitrogen and improves stability, colour, cetane, smell and cold properties like pour point.

The feedstock to a mild hydrocracker should be a light to medium Vacuum Gasoil (possibly in ERL case combined with 20% Visbreaker Gasoil) with typical gravity of 0.875-0.895 and relatively moderate inpurities (as an approximation; less than 1600 ppm Nitrogen, 1.5% sulphur, less than 10 ppm metals)

However The Mild Hydrocracker reactor unit has been kept shut. Only the section with the units fractionator column and stripper are currently in operation to handle the distillation of Natural Gas Condendate from the PetroBangla Gas fields.

5.2 Assessment Observations and Conclusions

1. The Hydrotreater/ Mild Hydrocracker Unit is mothballed.

2. Original design as hydro desulphuriser is for 1700 barrel/day which is not a good match for the Diesel fraction from the Crude Unit (approx 8500 barrel/day).

3. The unit should be reconsidered for return to desulphurization duty, also for the Visbreaker unstable Gasoil.

4. Restart after years in shutdown will require thorough inspection and maintenance.

5. Use of the fractionator for Condensate distillation only is a solution to the processing of increasing volumes, although not ideal.

5.3 A brief description of the Diesel Hydrodesulphurisation/ MHC unit

The feed to the MHC is combined with the net hydrogen-rich off-gas from the Platformer and in its planned setup a dedicated small Hydrogen steam methane reformer plant. The hydrogen is thoroughly mixed with the Vacuum Gasoil feed and compressed in the HDS Compressor to operating pressure (should be 60-80 kg/cm2 for Mild Hydrocracking of light Vacuum Gasoils). The charger heater boosts the temperature to approximately 400^o C and then the Hydrogen + hydrocarbons enter the Reactor vessel filled with cobalt-molybdena or nickel molybdenia hydrotreating catalyst.

The product leaves the reactor at higher temperatures as the process is exothermic and is cooled with cold vacuum gasoil feed through exchangers. The flow enters a pressure controlled separator where the gas, rich hydrogen combined with other saturated gasses is recycled to the compressor for return to the feed inlet together with fresh hydrogen.

In most refineries this gas mixture is first washed in an Amine treatment unit where the hydrogensulphide gas (H2S) is contacted with amines (mono or di ethylamine) and removed from the gas. ERL does not have such facility which then leaves the hazardous H2S gas to be removed without neutralization and burnt in the flare.

The bottom product from the separator is first cooled with exchangers and then enters the fractionator. The fractionator has its own reflux drum for separation of refinery gas, hydogensulphide gasses and sour water . The liquid products from the reflux return flow to the fractionator column. There is a stripper that will separate the Naphtha and LPG from the Diesel. The fractionator over head vapour is partially condensed by cooling water. The light gases from the reflux drum are sent to the fuel gas system. Part of the unstable naphtha from the reflux drum is sent as the reflux to the fractionator; the rest is sent to storage or to the visbreaker Naphtha stabilizer. The gas oil drawn as side stream is sent to the gas oil stripper. The stripped gas oil is cooled and sent to storage. The Mild Hydrocracked residue is stripped by steam in the fractionator bottom section. After cooling the MHC residue is sent to storage. The sour water from the fractionator overhead drum is sent to the sour water stripper. The sour water overhead gas is sent to the reactor feed heater stack for disposal

Apparently ERL decided to stop the Mild Hydrocracking operation some years ago.

Reasons must have been the limited possibilities of the rebuild unit to provide the right operating conditions for Mild Hydrocracking; temperature to be over 400 degr C and pressures in the region of 60-80 kg/cm2.

Revamping a reactor section would have involved replacing or strenghtening the skin of the reactor vessel to withstand higher pressures. If only moderate increase in pressure was possible than the expected output yield converted into Diesel is only 30 % or even less.

ERL may well consider to return the Mild Hydrocracker back into Hydrodesulphurisation of Visbreaker gasoil supplemented with some Crude unit gasoil to maximum capacity. Alternatively the heavier gasoil stream from the Crude Unit, the last distillate stream at 375 degr C may well be a better feedstock than the Vacuum Gasoil.

ERL currently operates only the MHC fractionator for the Nat Gas Condensate.

The condensate will be splitted in LPG, Naphtha, Kero and some Gasoil, in a similar fractionation process like in the crude oil unit. However the fractions will not have the exact cutpoints as the MHC fractionator is likely not equipped with sufficient trays, heighth, full reflux and strippers to allow a proper distillation of the NatGas condensates.

Also the unit is very small and not build for high volumes of light Naphtha and can as a consequence likely run less than 100 tons of condensate per day.

ERL may consider to review a procedure where up to 8 % of the condensate is directly spiked before the preheater section of the crude unit into the Arab Light and Murban crude and routed for processing in a normal way to the Crude Unit. This is equivalent to approx 250 tons per day of Nat Gas Condensate. The Crude unit should be able to accept this light condensate mixed with the crude as the Crude Unit preflash drum and the main distillation tower overhead condensors, reflux drum, finfan coolers and other reflux systems are all well designed in volume handling and pressure capacity to take a higher load. Pressure in the top of the column would likely become critical at 3-3.5 kg/cm2 which is not reached with current operation.

The advantage is a much better separation of Condensate fractions, and incorporation of the flow in the mainstream for further processing steps.

However ERL could run in the above suggested setup approx 100.000 ton/year of Nat Gas Condesate. This puts a limit then to the currently 170.000-200.000 tons of condensate being produced by Petrobangla and made available to ERL.

Note that current use of the Hydrotreater Stabilisation + Stripper section is a practical solution to refine light condensates, but the operation does not give better economics in energy use, fractionation and overall ease in handling condensates will be limited in current operation. Inclusion in the crude feed to the CDU as discussed is a far better alternative.

6. ERL Utilities

6.1 History

All installations that form the ERL utility have been built at different moments in ERL's history. Most recent was the investment in a water purification unit the Reverse Osmosis facility and the Steam Turbine Generator 2.

ERL's refinery units and its storage facilities cannot work without the availability of utilities like:

- Reliable electricity supply to power pumps and lighting. In ERL case the supply is fortunate to be independent of the national and local power suppliers in Chittagong, where electricity supply is interrupted often on a daily basis.
- Medium (5-16 kg/cm2) and low pressure (2-5 kg/cm2) steam for physical distillation processes like steam injection, as process component (hydrogen unit) and coil heating in exchangers or directly.
- Cooling water and cooling tower facilities for removal of surplus heat to the air. This is vital for reflux flows in all process units to remain efficient in securing proper fractionation.
- Demineralised water for boiler feed water as well as for water injection in process units.
- At ERL this is a new build Reverse Osmosis facility for clean process water for use in all non corrosive required areas like steam generation, desalters, and exchangers. It is understood that ground water in Chittagong has become salted to an unacceptable level.
- Oil-water separation facility for recovery of residual oil in waste water from the refinery process units.
- Compressed air for use as instrument air and also as utility air.
- Flare system.

6.2 Electricity supply

ERL refinery and storage/jetty facilities requires at full 33000 barrel/day capacity a constant reliable power supply on a daily basis of 3.3 - 3.8 MWh.

Load Distribution at ERL

Units	Required Load
Asphalt Bitumen Plant	200 KW
SCP Plant	700 KW
Reforming Plant	300 KW
Crude Distillation Unit	800 KW
Utilities	900 KW
Others	400 KW
Total	3300 KW min

ERL has three main suppliers of electricity on site. There is the Diesel generator for just power generation. The unit is run at its optimum level of around 1.2 MW. The most recent generator build in 2001 is a 3 MW capacity Chinese design conventional Natural Gas fired Steam Turbine Generator (STG-2). A second similar unit of also 3 MW capacity of Japanese design was build in 1987. Both units are the main consumer of natural gas at ERL with one unit run to balance the power requirement. Both units also provide process steam. All Natural Gas is purchased.

Name plate capacity	Year of commission	Name of the unit	Current expected safe output level
3000 KW	1987	3 MW STG-1	2000 KW
3000 KW	2001	3 MW STG-2	600 KW balancing
2000 KW	1998	2 MW Diesel Gen.	1200 KW

The STG units have an efficiency of approx 32 % (power + steam supply) which for these conventional unit designs is a typical and to be expected result. The 2001 unit is apparently slightly less efficient than the older STG. The Diesel unit is at 33-34% efficiency, which is also in normal range.

Of course these are conventional build steam turbine units and lack the latest technology such as in combined heat and power (CHP) or cogeneration facilities where efficiencies of 65-75%

on gas and distillate fired systems can be achieved, and the cost of very reliable power generation would be more than halved due to these efficiencies.

Although the nameplate capacity is unlikely to be met for 100% today, due to the age of the facilities, ERL can continue its 3.8 MWh power generation operation should one of the units go into a (in) voluntary shutdown. Maintenance to the units is carried out as routine and preventive and increased loads should not cause a major breakdown. However although the total MWh capacity is hardly adequate and leaves no spare capacity in case of addition of extra electricity demand at ERL in future projects.

ERL calculates the cost per generated KWh to be around 4 Taka, based on a Gas purchase price of 5.86 Taka per Ncbm Nat Gas. It should be noted here that international gas price levels are considerably higher than the ERL purchase price and have been around 16 Taka/Ncbm, without any transport cost taken into account. (based on the US Henry Hub futures natgas prices for 2005-2010). This is 3 times as much as the local Bangladesh price. (Calc; 6.3 USD/ mmBTU at 70 Taka-1 USD equals 15.60 Tk/cbm)

6.3 Steam production

ERL requires between 200 and 250 ton steam per day from dedicated steam providing boilers for its processing facilities. .

250 ton per day is a low quantity for a refinery like ERL. Expected steam requirement for an ERL type refinery would be approx 340 ton/day, based on the standard configuration and use per unit. One explanation is the ambient climate situation (30-35 degr C) in Chittagong and another the relative short distances between steam producer and steam consumer sites.

ERL has 2 dedicated boilers (1 water tube and one fire tube) for generation of medium pressure steam at the rate of 400-500 MT/day for process use.

ERL has some spare capacity and will have enough steam if one of the boilers is in shutdown, and usually runs with one boiler and one on standby mode.

Name of the unit	Name plate capacity	Year of commission	Current expected output
Boiler D	25 MT/HR	1983	13 MT/H(max)
Boiler C	16 MT/HR	1980	9 MT/H(max)
Boiler-E(forSTG 1)	18 MT/Hr	1987	
Boiler-F(forSTG 2)	20 MT/H	2001	
WTP-1	50 MT/H	1987	40 MT/H
WTP -2(Chinese)	12 MT/H	2001	

All units are (purchased) Natural Gas fired and of conventional design. Efficiencies are expected at less than 80% for the dedicated boilers given age and limited use of waste heat except preheat the feedwater to 60 degr C..

One ton of steam requires at this efficiency approx 67 cbm gas to be burned.

ERL may consider to convert its least efficient boilers with a fuel fired capable burner. Although Nat Gas is cheaper than liquid fuel in Bangladesh, these Boilers should be able to run on the very heavy cheap sludge like the tar from the Vacuum unit, Visbreaker and API separator slops.

6.4 Demineralised water and cooling water supply

Salt levels in the Chittagong ground waters have recently reached an for ERL units unacceptable levels (1100 ppm NaCl) causing corrosion in pipes and vessels.

To produce demineralized water, ERL treats ground water in a recently added Reverse Osmosis (RO) unit followed by and Ion-exchange unit. Demiwater capacity of 50 Mts/hour is more than adequate for power boilers and process boilers.

RO process unit is commissioned in 2009 and in use since then. It is a filtration method that removes many types of large molecules such as salt and other ions from solutions by applying pressure to the solution when it is on one side of a selective membrane filter. The result is that the solute with salt and impurities is retained on the pressurized side of the membrane and the pure water is allowed to pass to the other side.

This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 12–17 kg/cm2 or even higher in case of salt concentrations over 1000 ppm. The ERL unit is built in 2 units of 20 tube stacks with inside the filters. To clear the filters there is a monthly programmed backwash pressure applied to push all impurities out of the tubes.

The process is efficient and requires only pressurised water beside routine maintenance of the filters. ERL advises a cost of 57 Taka per cbm clean water.

For its cooling water ERL uses either groundwater and dedicated rainwater reservoirs nearby. ERL recycles its cooling water continuously.

Make up water supply is less than 30 cbm/hour. Total cooling water requirement is supported by 3 water pumps with a capacity of 70 cbm/hour. ERL has two cooling block facilities both based on mechanical draft.

These are concrete blocks of cooling towers with a natural and forced draft caused by a fan at the discharge end which pulls air through the tower. The fan induces hot moist air out to the discharge. This produces low entering and high exiting air velocities, reducing the possibility of recirculation in which discharged air flows back into the air intake. It is an efficient system, although there is no use for the rest heat from the cooling towers in a 30-35 degrees C climate.

Cooling water is used in the reflux and stripper streams and fin fan overhead cooling in CDU, Vacuum unit and Visbreaker fractionating towers.

The process is cheap, (approx 1 Taka/cbm) simple and after the towers are build they require only some maintenance of the fans which are robust.

ERL has sufficient cooling capacity to serve the whole refinery and has surplus if required.

6.5 API waste oil collection and separation system

Various units at ERL will leave oil in the waste water. The crude unit desalter, the reflux drum condensation water and the exchangers all over the refinery due to small leaks and lose oil in the fractionation process. Most of waste oil comes from the storage facilities and oil drains.

The API separator is a gravity separation device designed to support the rise and velocity of oil droplets in water based on their density and size. ERL has an approx. 60 meter by 5 meter facility build at the edge of the refinery. It is a concrete bassin of 2 meters depth with water overflow into several compartments to stir the oil droplets. The design of the separator is based on the specific gravity difference between the oil and the wastewater. Based on that design criterion, most of the suspended solids will settle to the bottom of the separator as a sediment layer, the oil will rise to top of the separator, and the wastewater will be the middle layer between the oil on top and the solids on the bottom.

Typically, the oil layer is skimmed off and subsequently re-processed or disposed of, and the bottom sediment layer is removed by a chain and scraper and a small sludge pump. In ERL case the sludge is sold to locals as a burner fuel. The remaining water layer is apparently sent to the river without further treatment.

ERL may consider applying some type of biological treatment unit for removal of undesirable dissolved oil and other chemical compounds. However due to the small size of the refinery the amount of such waste is very small, or considered not a danger to the environment.

6.6 Compressed Air system

ERL has 2 dedicated aircompressors for supply of compressed air. The compressed air delivered is dried in an efficient air drying system. The complete system has adequate capacity to meet instrument air need and as well as utility air (for cleaning/drying) need.

6.7 Flare

ERL like any other refinery requires a flare to eliminate waste gas and burn any unwanted gasses that are the result of stripped gas/ liquids in overhead condensors and other separators. It is also the safety outlet for fast removal of hydrocarbons from units that need to be rapidly shut in a controlled procedure. The flare act as safety systems for non-waste gas and any disposable material is released via a knock out drum and pressure relief valve when needed to ease the strain on any processing equipment.
The flare stack is at the edge of the refinery site, well away from storage tanks and processing facilities and has a pilot burner with piezo element for re-ignition. There is no real capacity constraint.

7. ERL Support process units

7.1 ERL Merox units

These units are basic treatment facilities to neutralize mercaptans (hydrogen and hydrocarbon sulphide components) in products. Mercaptans cause unwanted smells, odours, colouring, instabilities.

The Merox units leave the sulphur in the hydrocarbon but change the molecular structure into hydrocarbon disulphides, which is harmless and without the typical mercaptan characteristics.

Merox processes are simple and relative cheap to build and to operate. The basic operation is a wash with caustic soda water mixture and followed by oxidization with air. The process cannot be compared with Hydrotreatment where sulphur is removed from the hydrocarbons altogether in a reactor.

ERL has a Kerosine Merox; 125.000 ton/year

a Naphtha Merox; 100.000 ton year, both build in 1968

a LPG Merox ; 24.000 ton/year, build in 1985

The conventional Merox process for the removal of mercaptans i.e., sweetening of jet fuel or kerosene or Naphtha is a one-step process. The mercaptan oxidation reaction takes place in an alkaline (caustic soda) environment as the feedstock jet fuel or kerosene, is mixed with compressed air. At ERL the Kero and Naphtha from the crude unit are first prewashed in a prewash drum with caustic soda to remove any unwanted hydrogen sulphides that will interfere with the actual Merox process.

Following the prewash the jet fuel or kerosene feedstock enters the Merox reactor from the caustic prewash vessel at the top along with injected caustic soda and with compressed air, and flows through a fixed bed of catalyst in the reactor vessel. The Merox reactor is a vertical vessel filled with catalyst that consists of charcoal granules that have been impregnated with a metal carbon catalyst. (UOP). It leaves the bottom of the reactor into a separator. Here the Caustic Soda is recovered through gravity settlement and returned to the top of the reactor. The treated product is removed and further washed in water to remove all remaining caustic soda. The caustic solution remains in the caustic settler so that the vessel contains a reservoir for the supply of caustic that is intermittently pumped back into the reactor to maintain the alkaline environment.

Product is then dried in a salt filter and finally treated via a clay filter to remove all other impurities.

The ERL the LPG Merox Unit is a two-step process contrary to the Kero Merox and has an Extraction and a Caustic Regeneration section. The Extraction Section removes the mercaptans from the LPG stream through extraction with a circulating caustic solution forming sodium mercaptides. The Caustic Regeneration Section regenerates the caustic by heating and oxidizing the product into disulfides, which are then removed prior to returning the regenerated caustic solution for another extraction cycle to the extraction reactor.

ERL's Kero Merox capacities is not sufficient to treat all produced Kerosine. At present about 35% of the stream can be treated, but Kero from the current cude oil slate does not contain a high level of mercaptans and the blended finished product will be marketable.

The Naphtha Merox is just about sufficient to treat the Light Naphtha stream, which currently is exported. However increase in volumes of Condensate may require additional capacity to be build.

The LPG Merox has sufficient capacity to treat at present all ERL produced LPG (approx 14000 ton year). This Merox is important as mercaptans tend to occur more in LPG than in other light liquid products.

7.2 ERL Hydrogen Unit

ERL recognized a need for extra hydrogen to complement the Platformer generated hydrogen for use in the Mild Hydrocracker Unit. The hydrogen production facility was build as a steam methane reformer and is part of the ERL Secondary Conversion Project completed in 1995.

Capacity as per ERL indication is rated at 790 ton/year (1.08 million cubic feet/day).

This is small for an industrial hydrogen plant, but matches the required hydrogen for the on site mild hydrocracker unit. Both units have been shutdown for some time now.

ERL keeps the hydrogen unit in very good condition and can be expected to return in operation at short notice if required. (On basis of a visual superficial inspection)

Hydrogen units are relative expensive to build due to the required construction parameters for the reactor and will, with routine maintenance, remain in service for a very long time.

The ERL steam reforming plant consists of four basic sections :

- The first part is the feedstock pretreatment where sulphur and other contaminants are removed.
- Natural gas and/ or refinery methane gas is first compressed to about 20 kg/cm2. The feed gas is then preheated to 350 degr C with the reformer's effluent gas and hydrotreated to convert the various sulfur compounds (such as mercaptans, di sulfides) to hydrogen sulfide. The feed gas is then passed through the three small desulfurization reactors, containing a zinc/aluminium oxide catalyst, which adsorbs the hydrogen sulfide. Low-sulfur feeds like Natural Gas may not require this hydrotreating step.
- The second process is the steam methane reformer itself .
- The sulfur-free gas is mixed with a fixed amount of superheated steam (750-900 degr C) which converts the feedstock and the added high pressure steam to a syngas (a mixture of hydrogen and carbon monoxide). The steam-to-hydrocarbon ratio is kept within a range of 3 to 1 to prevent forming of coke on the nickel based reforming catalyst. The reforming reactions are highly endothermic, additional heat which is supplied by Natural Gas fired burners around the with catalyst filled vertical reactors is required to maintain the reaction temperature as the mixture flows down through the ERL unit's 6 catalyst-filled reformer tubes.
- The third section is the syngas effluent heat recovery and the carbonmonoxide (CO) shift reactor to increase the hydrogen yield.
-
- Effluent gas containing carbon monoxide CO and steam H2O is passed over the hot gas-shift catalyst, where the water-shift gas reaction occurs. Additional hydrogen H2 is

generated from the carbon monoxide being converted to carbondioxide CO_2 byproduct as the effluent gas flows down through the fixed catalyst shift reactor containing a metal based oxide catalyst. The water-shift reaction is exothermic, which results in a temperature increase across the reactors, and the heat is transferred via the heat exchanger of the unit.

- The final section is to purify the raw hydrogen which still contains carbon oxides.

The ERL unit employs a pressure swing adsorption (PSA) unit to achieve the final product purity. This PSA process produces a hydrogen stream of 99.9% purity. It separates carbon monoxide, carbon dioxide and unconverted hydrocarbons from hydrogen. The inpurities are collected via adsorption where the adsorbers are rotated through a higher-pressure section, followed by a pressure reduction, which allows the contaminants to be released from the adsorber. The hydrogen gas passes through the adsorber as almost-pure hydrogen. The contaminants flow into a fuelgas surge drum and send to the flare.

Altogether this is a unit built with the latest technologies in hydrogen production and if required for future hydrogen it should be expected to start operation without major costs or time.

8. ERL storage facilities

Surrounding the refinery are the storage tanks for crude oil, intermediate or rundown product and tanks for finished products.

ERL maintenance does allocate sufficient money and time to keep the tanks in very good condition. Most of the tanks were first built together with the ERL processing facilities in 1967. Although only a superficial examination took place, the tanks and connecting lines and manifolds were all in very good condition, freshly painted, properly repaired, all with clear indications for the right product contents, safety codes and tank sizes. Where visual examination was possible there appeared no signs of major leaks due to less integrity of the tank horizontal and vertical plating. Some oil was found the bunded area and in the nearby gulley and streams, but this was the result of tank and pipeline cleaning and only of minor concern. All tanks are connected to a central monitoring system with auto-tank gauging system from Motherwell with on line information about movement, volumes, densities, low and high level alarms.

This sophisticated system is operated from the Oil Movement office inside the tank farm.

Since most liquids can spill, evaporate, or seep through , special consideration must be made for their safe and secure handling. This involves the building of a bunding, or containment dike, around the tank farm area, so that any leakage may be safely contained. ERL bunds looked well maintained and without gaps.

Some storage tanks have a floating roof in lieu of the fixed roof and structure. This floating roof rises and falls with the liquid level inside the tank, thereby decreasing the vapor space above the liquid level. In particular in Bangladesh with temperatures all year around 35 degrees storage losses of petroleum is critical and floating roofs are considered a safety requirement as well as a pollution prevention measure for volatile petroleum products.

The following table lists all tanks at ERL and their current service

ERL Tank allocation	*type*	st tanks	gross capacity cbm		net capacity cbm	ERL output yield	ERL output approx cbm daily rundown	year import	days capacit	turns per year
Crude		7	278000		241072	91.5%	4750		51	
Gas Condensate		4	24500		22294	8.5%	500		45	
		11	**302500**	**87%**	**263366**		**5250**		**50**	
LPG	**finished**	**2**	2200		2050	1.0%	52		39	
Naphtha	**export**	**6**	43200		38361	6.8%	357		108	
Light Na comp	**interm.**	**2**	2500		2386	0.6%	31		76	
HOBC	**interm.**	**1**	2000		1645	2.8%	147		11	
Gasoline comp	**interm.**	**3**	4400		3928	4.3%	226		17	
Gasoline	**finished**	**1**	2000		1645	5.9%	310		5	
Import Gasoline	**import**	**1**	13000		12491			80000		6
S Kero	**finished**	**3**	6000		5728	23.0%	1207		5	
Kero JP1	**finished**	**1**	2000		1909	0.3%	16		121	
Diesel	**finished**	**4**	18278		17529	27.2%	1427		12	
Diesel import	**import**	**2**	63000		56411			2000000		32
Jute oil	**finished**	**1**	2000		1909	1.4%	73		26	
LVacGO	**interm.**	**1**	1300		1244	2.0%	105		12	
HVacGO	**interm.**	**2**	2600		2487	3.0%	157		16	
MHC feed	**interm.**	**2**	1000		950	1.0%	52		18	
RCO Atmos Resid	**interm.**	**5**	65000		62563	33.0%	1731		36	
Fuel Oil	**finished**	**5**	33570		32118	24.0%	1259		26	
Bitumen	**finished**	**5**	2500		2378	4.1%	215		11	
water		**1**	2000		1909					
		48	**268548**	**93%**	**249641**		**5145**		**49**	

8.1 Quality of the Marketing companies storage facilities

Similar to the situation at ERL, the majority of the marketing company's tanks date back to 1968 and even earlier to 1956 for the POCL terminal. Maintenance for all three product terminals is (on a superficial basis) done on a routine basis and the tanks all are in good and excellent condition, well painted and properly coded.

Some oil was found in the immediate areas around the tanks, and may have been the result of tank cleaning during maintenance. Tanks are routinely rotated for essential maintenance and the terminals are in continuous operation at all times.

POCL, beside the petroleum products, also manages a lubricants blending and filling plant with a blending capacity of 25000 ton/per year. It fills drums (159-200 liter) and a variety of cans and bottles. Total storage for base oils is 10220 tons. Drums are locally produced.

POCL also has the use of a well equipped laboratory for basic testing of the imported and blended product qualities.

MPL and JOCL do not blend and process lubricants, but both use dedicated warehouses on their sites to store finished grades lubricant oil delivered respectively from BP and Mobil sources.

Combined Marketing Companies Chittagong Tank allocation

	capacity ton	cap cbm	throughput year 08-09 cbm	sales yield	tank turnovers per year	days capacity equiv
HOBC	9549	12648	88132	2.5%	7	52
Gasoline MS	16760	22199	130672	3.7%	6	62
S Kero	47286	59108	371679	10.5%	6	58
Kero JP1	24213	30266	324733	9.2%	11	34
Diesel	117052	138523	2432651	68.5%	18	21
LS Diesel	1680	2012	2370	0.1%	1	310
Jute oil	4713	5386	16824	0.5%	3	117
LDO	1810	2011	63	0.0%	0	11652
SBP	194	259	1262	0.0%	5	75
MTT	1804	2313	6552	0.2%	3	129
Fuel Oil	36673	38603	169373	4.8%	4	83
Luboil	10220	11169	4456	0.1%	0	915
	271954	324497	3548767	100.0%	11	33

With all tanks, ERL and the Marketing companies, there is 574000 CBM of total product storage (net, above heels) and 263000 CBM for crude oil (net, above heels).

APPENDICES:

1. Platts quotations - Products

Platt's Mid

	Products Arab Gulf Butane FOB Cargoes	Products Arab Gulf Propane FOB Cargoes	Products Singapore Mogas 95 Unl	Products Singapore Mogas 92 Unl	Products Singapore Naphtha Cargoes	Products Singapore Jet/Kerosene	Products Singapore Gasoil 0.05%	Products Singapore Gasoil 0.25%	Products Singapore Gasoil 0.5%	Products Singapore HSFO 180 CST	Products Singapore HSFO 380 CST	Products Arab Gulf Unleaded 95 FOB Cargoes	Products Arab Gulf Naphtha
01-Jan-08	816.18	811.18	100.51	99.56	93.13	106.18	107.91	106.91	105.70	475.50	467.19	96.47	810.77
01-Feb-08	796.37	792.66	105.07	104.13	95.07	111.10	113.32	112.38	111.20	475.19	465.25	102.09	833.20
01-Mar-08	801.43	796.43	109.78	109.17	97.61	125.37	129.04	127.94	126.19	503.51	489.19	106.28	858.46
01-Apr-08	813.23	804.59	118.08	117.09	102.61	138.58	141.98	141.05	138.34	546.01	517.48	114.87	905.75
01-May-08	875.20	858.45	131.13	130.06	113.69	159.58	161.22	160.86	158.62	613.28	580.22	128.01	1000.83
01-Jun-08	897.33	872.33	140.30	138.78	125.25	164.88	169.36	168.63	166.45	646.76	626.28	136.56	1080.92
01-Jul-08	907.65	863.96	135.27	134.70	125.46	167.28	168.01	167.46	165.97	734.01	715.49	131.21	1093.60
01-Aug-08	793.40	763.40	115.49	113.98	108.37	137.65	135.26	133.89	132.17	674.03	661.10	111.07	937.62
01-Sep-08	799.41	769.41	107.10	104.82	91.97	121.50	121.04	119.94	118.93	590.54	581.30	102.35	799.85
01-Oct-08	568.00	554.90	79.50	77.13	51.12	90.09	88.85	86.10	83.98	400.96	391.28	75.10	453.31
01-Nov-08	362.65	364.40	48.41	47.45	29.09	75.08	73.77	70.67	68.77	243.57	232.67	44.96	252.62

01-Dec-08	342.90	353.20	41.05	38.88	31.00	59.02	61.82	59.64	58.01	228.50	220.42	38.33	261.05
01-Jan-09	456.89	458.68	52.23	48.97	42.58	60.15	59.99	59.03	58.36	256.47	250.13	50.19	360.46
01-Feb-09	428.28	429.03	57.97	55.42	46.84	52.85	52.40	50.48	49.10	257.59	254.48	55.44	386.26
01-Mar-09	357.86	372.59	54.20	53.14	46.53	53.34	54.49	53.14	52.10	246.11	243.52	52.23	397.60
01-Apr-09	389.64	375.07	60.46	58.27	49.35	59.10	60.19	59.05	58.09	290.29	287.37	58.97	432.18
01-May-09	411.28	373.03	68.50	65.48	54.01	64.07	65.56	64.97	64.06	346.98	344.98	66.87	477.43
01-Jun-09	516.89	459.11	77.15	75.01	65.86	76.45	77.05	76.69	76.31	401.76	398.96	75.29	572.99
01-Jul-09	494.22	462.48	72.83	70.84	62.92	72.39	72.00	71.65	71.08	402.67	400.90	71.05	548.82
01-Aug-09	563.40	535.35	82.13	80.13	70.37	78.67	79.84	79.59	79.02	437.72	435.37	80.05	615.16
01-Sep-09	575.12	553.74	75.63	73.84	66.80	74.58	75.04	74.82	74.65	425.72	424.33	73.33	579.61
01-Oct-09	615.39	607.48	77.71	76.05	69.20	80.07	80.45	80.14	79.64	443.71	440.69	75.29	605.07
01-Nov-09	689.70	685.95	81.89	79.88	76.21	84.95	84.59	84.40	84.02	470.20	466.58	79.60	664.04
01-Dec-09	724.77	714.05	81.85	78.95	78.28	83.24	81.71	81.52	81.29	468.91	464.99	79.04	672.86
01-Jan-10	727.93	730.63	88.01	84.87	80.66	85.87	85.13	84.80	84.24	486.44	480.72	85.35	695.93
01-Feb-10	648.92	651.42	86.49	83.55	75.76	82.23	82.79	82.64	82.30	462.92	455.34	84.14	658.23
01-Mar-10	670.46	681.24	90.86	88.48	80.84	87.49	88.26	88.03	87.78	470.56	460.07	88.60	705.16
01-Apr-10	687.86	691.67	94.06	91.91	83.13	94.82	95.61	95.24	94.77	492.02	483.62	91.89	728.20
01-May-10	677.05	674.30	85.12	83.04	77.43	88.12	88.71	88.30	87.91	459.73	455.37	82.56	675.62
01-Jun-10	621.75	620.84	83.26	81.54	72.42	86.64	86.75	86.20	85.67	441.17	437.19	81.07	638.33
01-Jul-10	572.25	557.61	82.42	80.37	68.57	85.32	85.83	85.23	84.69	446.09	438.14	80.20	607.87
01-Aug-10	627.88	609.48	82.52	80.83	73.31	87.15	87.62	87.23	87.14	454.26	445.28	79.71	639.12

2. PLATTS CRUDES

Crudes Platt's Mid

	Dubai 1st month	Oman 1st month	Murban	Al Shaeen	Forcados
01-Jan-08	87.37	88.55	92.05	85.41	93.89
01-Feb-08	90.02	90.68	94.97	88.56	97.37
01-Mar-08	96.76	97.86	102.22	95.04	106.09
01-Apr-08	103.41	104.09	109.44	101.89	113.28
01-May-08	119.50	119.80	125.46	117.64	127.87
01-Jun-08	127.82	128.32	134.56	126.10	137.85
01-Jul-08	131.27	132.81	137.94	129.33	138.16
01-Aug-08	112.86	113.28	119.50	111.23	116.85
01-Sep-08	95.90	96.13	101.32	94.51	103.30
01-Oct-08	67.42	67.96	71.12	66.25	76.83
01-Nov-08	49.84	50.04	53.05	48.96	57.14
01-Dec-08	40.53	40.99	43.21	39.86	45.22
01-Jan-09	44.12	44.45	46.44	43.26	47.84
01-Feb-09	43.09	43.52	44.71	42.83	47.03
01-Mar-09	45.59	45.83	47.75	45.57	48.58
01-Apr-09	50.10	50.16	52.33	49.84	51.10
01-May-09	57.85	57.96	59.96	57.72	59.02
01-Jun-09	69.41	69.47	71.50	69.27	70.14
01-Jul-09	64.82	65.08	66.80	64.72	65.56
01-Aug-09	71.34	71.57	73.48	71.11	73.43
01-Sep-09	67.64	68.16	69.68	67.66	68.41
01-Oct-09	73.15	73.34	75.06	73.51	73.85
01-Nov-09	77.71	77.88	79.02	77.70	77.95
01-Dec-09	75.42	75.48	76.84	75.06	75.40
01-Jan-10	76.69	77.01	78.19	76.37	77.53
01-Feb-10	73.48	73.92	75.29	73.38	74.99
01-Mar-10	77.31	77.72	79.18	76.79	80.75
01-Apr-10	83.59	83.67	85.38	82.68	86.39
01-May-10	76.78	77.04	78.86	76.34	77.48

01-Jun-10	73.99	74.18	75.90	73.70	77.00
01-Jul-10	72.49	72.59	74.42	72.49	76.66
01-Aug-10	74.09	74.37	75.93	74.25	78.56

3. ERL OUTPUT/ INTAKE VOLUMES

ERL intake/output Mtons

YEAR	LPG	NAPTHA	MS	HOBC	SBPS	MTT	JP-1	SKO	HSD	JBO	LDO	HSFO	BITUMEN	TOTAL
1999-2000	13,071	59,320	76,322	78,192	882	5,948	3,834	321,463	375,104	17,314	4,069	339,366	53,190	1,348,075
2000-2001	13,061	41,402	91,480	68,479	414	4,827	1,124	339,540	333,629	19,595	2,204	346,431	49,245	1,311,431
2001-2002	12,409	37,251	101,162	40,134	244	4,966	4,578	306,952	330,448	13,705	2,007	281,838	67,744	1,203,438
2002-2003	15,809	68,804	98,374	40,791	315	5,675	4,550	358,745	379,024	20,637	2,665	382,851	44,359	1,422,599
2003-2004	16,029	73,363	78,761	43,287	917	6,686	1,585	338,126	344,507	18,458	2,418	322,999	59,600	1,306,736
2004-2005	14,898	81,029	59,625	39,327	955	7,120	0	204,864	396,898	17,336	2,485	288,614	50,178	1,163,329
2005-2006	16,083	121,508	75,714	20,932	1,310	7,320	5,480	311,524	383,085	18,190	2,289	360,876	59,501	1,383,812
2006-2007	12,495	122,667	66,046	13,046	1,244	6,174	0	315,229	335,714	18,571	2,480	273,195	56,379	1,223,240
2007-2008	9,986	138,521	67,046	13,439	1,174	5,405	5,678	262,978	339,131	13,538	2,418	290,463	43,722	1,193,499
2008-2009	6,278	93,759	38,821	13,372	887	4,744	6,064	190,059	245,320	16,365	2,144	191,991	34,140	843,944
Average	13,012	83,762	75,335	37,100	834	5,887	3,289	294,948	346,286	17,371	2,518	307,862	51,806	1,240,010

YEAR (FISCAL)	Crude Oil/NGC RECEPTION				Crude/NGC Processed	Product from all Units	ONSTrEAM DAYS
	ALC	MURBAN	CONDENSATE (NGC)	TOTAL			
1999-2000	626,972	609,077	72,731	1,308,780	1,377,600	1,348,075	351 Days
2000-01	737,613	544,834	61,522	1,343,969	1,350,420	1,311,431	342
2001-02	713,432	562,235	56,374	1,332,041	1,249,240	1,203,438	312
2002-03	624,057	700,584	72,509	1,397,150	1,455,000	1,422,599	359
2003-04	503,293	670,015	91,311	1,264,619	1,315,600	1,306,736	341
2004-05	671,449	474,864	98,874	1,245,187	1,226,000	1,163,329	310
2005-06	690,117	654,807	92,986	1,437,910	1,405,000	1,383,812	349
2006-07	550,158	557,790	115,852	1,223,800	1,269,400	1,223,240	330
2007-08	580,990	521,694	162,654	1,265,338	1,213,800	1,193,499	318
2008-09	499,503	393,488	206,082	1,099,073	884,800	843,944	246
Average	619,758	568,939	103,090	1,291,787	1,274,686	1,240,010	323

TAKA IN LAKH [redacted]

	2007 - 2008			2006 - 2007		
	Tk. 7,447.90			Tk. 7,368.40		
	ERL	SCP	TOTAL	ERL	SCP	TOTAL
Salaries & Wages	1,171.36	91.84	1,263.20	1,174.84	95.20	1,270.04
Employees other cost	741.94	65.76	807.70	728.88	54.35	783.23
Chemical consumed	188.11	7.66	195.77	227.66	6.43	234.09
Stores & spares consumed	716.32	---	716.32	448.59	—	448.59
Fuel, power and Water	320.65	8.61	329.26	387.87	21.18	409.05
Bakhrabad Gas	923.79	249.02	1,172.81	942.89	219.86	1,162.75
Insurance	119.48	79.51	198.99	147.23	83.51	230.74
Crude Oil Handling Expenses	16.77	—	16.77	3.66	—	3.66
Repair & Maintenance	107.78	58.33	166.11	135.90	36.23	172.13
Shutdown Expenses	54.14	---	54.14	110.05	–	110.05
Transport Expenses (Note-19.01)	173.59	18.76	192.35	163.93	17.92	181.85
Training Expenses	4.67	--	4.67	0.93	–	0.93
Depreciation (Note- 3.03)	528.17	1,794.10	2,322.27	529.70	1,794.13	2.323.83
Technical Assistance	---	---	---	15.87	—	15.87
Others	7.54	---	7.54	21.59	—	21.59
Total	**5,074.31**	**2,373.59**	**7,447.90**	**5,039.59**	**2,328.81**	**7,368.40**

Own	20.75	1.51	22.26	14.27	1.46	15.73
Hired	152.84	17.25	170.09	149.66	16.46	166.12
Total	**173.59**	**18.76**	**192.35**	**163.93**	**17.92**	**181.85**

Bangladesh

Asian Development Bank

STRENGTHENING OF THE HYDROCARBON UNIT IN THE ENERGY AND MINERAL RESOURCES DIVISION (PHASE-II)

REFINING AND MARKETING

RFP HCU/CS-06

MARKETING ASSESSMENT REPORT

SOFRECO

December 2010
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Société Française de Réalisation, d'Etudes et de Conseil
92-98, boulevard Victor Hugo 92115 Clichy Cedex - France
Tél : +33 1 41 27 95 95 - Fax : +33 1 41 27 95 96
E-mail : infra@sofreco.com - Site Web : www.sofreco.com

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ACRONYMS

ADB	Asian Development Bank
ASD	Average Days of Storage
BBS	Bangladesh Bureau of Statistics
BERC	Bangladesh Energy Regulatory Commission
BG	Broad Gauge
BIWTA	Bangladesh Inland Waters Transport Authority
BIWTC	Bangladesh Inland Waters Transport Corporation
BPC	Bangladesh Petroleum Corporation
BR	Bangladesh Railways
CNG	Compressed Natural Gas
CY	Calendar Year (January-December)
DG	Dual Gauge
ERL	Eastern Refinery Ltd
FO	Heavy fuel oil (Furnace Oil)
FY	Fiscal Year (July-June)
GDP	Gross Domestic Product
HCU	Hydrocarbon Unit
HOBC	High Octane Blending Component (Premium Gasoline)
HSD	High Speed Diesel
IMF	International Monetary Fund
IPP	Independent Power Producer
JBO	Jute Batching Oil
KPCL	Khulna Power Company Ltd (IPP)
KPS	Khulna Power Station (PDB)
LPG	Liquefied Petroleum Gases
MG	Meter Gauge
MI	Main Installations (Chittagong depot)
MS	Motor Spirit (Regular Gasoline)
PDB	Power Development Board
PSDP	Power Sector Development Programme
PSMP	Power Sector Master Plan
QRPP	Quick Rental Power Plants Programme
REB	Rural Electrification Board
SKO	Kerosene
WB	World Bank

EXECUTIVE SUMMARY

1. The context

As in many natural gas countries, oil is not a key element of the energy sector in Bangladesh, except for transport. Oil accounts for 22 % of the commercial energy consumed, and the sales have grown by less than 1% p.a. over the past few years. Consumption patterns are much imbalanced, with a strong orientation towards transportation fuels, in particular diesel oil, where it is more difficult for gas to reach a significant market share.

However, the golden age of abundant and cheap energy (i.e. gas) is over in Bangladesh. Gas fields are being depleted, and neither field enhancement nor new discoveries allow – at least for the time being – to offset the decrease of the production of the fields currently in operation. Bangladesh has now entered a transition period where the share of oil products in the energy mix is going to increase at a very fast pace, in particular for the generation of electricity.

As gas availability fades, gas consumption will need to be re-oriented towards these captive markets where gas remains the best, due to intrinsic qualities, if not the only fuel, such as fertilizers, food, glass and metal surface treatment, etc. Gas will also certainly keep on feeding the hundreds of thousands of households that are already connected to the network, as well as the thousands of cars that run on CNG, although any further development of these markets is likely to be suspended, if not abandoned.

Conversely, power generation has initiated a strategic change based on a massive shift from gas to oil products. This makes fuel oil and diesel oil the new preferred fuels, at least over the short and medium term. We expect the oil demand to double in just a few years, and reach 7.3 million tons[1] in 2015, 9.9 million in 2020 and 17.5 million in 2030. The driving force will be the power generation sector, with 3.1 million tons consumed in 2015, 4.6 million in 2020 and 9.5 million in 2030.

Such a strong development will exacerbate the problems that the oil marketing and distribution industry is currently facing. This report presents our assessment of the current situation of the marketing and distribution of the **main six products** used in the Bangladeshi market (premium and regular gasoline, diesel oil, kerosene, fuel oil and jet fuel), which account for 93% of the whole demand. It focuses on the **market and logistics domains** (sales, storage, transportation).

2. Main issues

When it comes to strategic products, the key challenge for the operators – and all stakeholders, including the State as main shareholder, policy maker and, still to a large extent, industry regulator – is to ensure that the right products are delivered at the right place in the right time. Then **security of supply** remains, by far, the #1 issue to be addressed. It

[1] For the main six fuels (premium and regular gasoline, diesel oil, kerosene, fuel oil and jet fuel).

implies to develop a second port of entry in Bangladesh; to increase the storage capacity of some depots; and to improve transport capacity between depots.

Production, imports, main storage and dispatch facilities are concentrated in one single spot. Every single drop of oil consumed in Bangladesh, except a small quantity available from the gas field plants has to travel through Chittagong, and there is currently no other way around. While the physical patterns of the country have obviously decided of such a de facto monopoly, it puts the security of supply of the country at risk. There is clearly a need for a **second port of entry in Bangladesh**, in particular because the upside potential for additional infrastructure in Chittagong is no longer commensurate with the strong development of the oil market. The port of Mongla is an option, but accessibility is constrained by the 5.5-meter (18 ft) draft available along the 100-km long channel that connects the port to the Bay of Bengal. The maximum capacity of the ships is reportedly 4,000 tons.

Lack of storage capacity is the second issue. It mainly concerns the three transfer depots of Godenail, Fatullah and Daulatpur, i.e. these depots that both serve their local consumers, and play the role of hubs where oil products received from the Main Installations (MI) of the three Marketing companies e.g. Padma Oil Company (POCL), Meghna Petroleum Ltd (MPL) and Jamuna Oil Company Ltd (JOCL), all located at Chittagong, by coastal tankers are forwarded to local depots downstream by shallow draft tankers (SDT), train or tank (road) lorry. Two products are at stake: diesel oil and jet fuel.

The demand of **diesel oil** is tightly linked to the needs of the agricultural sector. It doubles during the dry season in these areas where cultivation requires intensive irrigation provided by diesel-run (and electricity) pumps, e.g. in the Rajsahi division. The seasonal swing hits particularly the storage capacity of the Godenail and Fatullah depots, which supply the Baghabari depot. In these two depots, the number of average days of storage, which is already low in the wet season (no more than a week), falls to around 4 days in the dry season. This figure is well below what a smooth and efficient operation requires, in particular whenever insufficient river draft in the Jamuna river prevents SDTs from supplying Baghabari for days or weeks. The situation at Daulatpur, which feeds 4 northern depots by rail, while less dramatic, is also worrying.

The storage capacity of **jet fuel** in the Dhaka area is definitely insufficient. With 4 days of storage in Godenail and 4 days at the airport (KAD) depot, the capacity needs to be substantially increased, as evidenced by recent events in September that have demonstrated the high vulnerability of jet fuel supply to external movements.

The transport of oil products between the MI and depots, or between transfer hubs and regional depots, suffers from several drawbacks. **Marine and waterways transport** account for 86% of oil transport. It benefits from a large – indeed oversized – number of coastal tankers that is currently more than sufficient to supply the main marine routes. However, with rocketing oil demand, in particular fuel oil for power generation (which cannot be moved by pipeline), the transport demand will have exceeded the supply availability within a few years.

Insufficient dredging of both river channels and unloading sites at many depots do not enable marine transport to take full advantage of this cheap, efficient – and perfectly suitable for Bangladesh -- means of transport.

With 14% of all oil products moved across Bangladesh, **railway transport** retains a modest share of the overall movements. However, rail transport is highly strategic as it is the only way to reach many depots, in particular in the Rajshahi Division where siltation and scarce water flow in the Jamuna and Padma river systems have dramatically reduced, if not halted, navigability. Railways suffer from a recurrent shortage of engines and wagons, in particular in the meter gauge system, and from the near saturation of the Chittagong-Akhaura section of the eastern corridor. In addition, technical problems on the Jamuna Bridge reportedly limit the number of trains allowed to cross the bridge.

The doubling of the Chittagong-Tongi meter gauge line is underway and will bring a much needed relief in a corridor that accounts for 40% of the overall railway traffic in Bangladesh. Also, announcements are made periodically by BR on the procurement of additional engines and wagons, including tanker wagons.

Improving the transportation system has become a sheer necessity, considering the enormous additional volumes of fuel oil and diesel oil that the implementation of oil-run power plants has already started to generate. The time has come to revive a long standing project and to seriously consider building a **dedicated products pipeline** from Chittagong to the Dhaka area. While such a pipeline will not be able to carry fuel oil – due to high viscosity – and jet fuel – due to the risk of contamination by other products – the requirements for middle distillates and light products seem to fully justify the implementation of this type of infrastructure. The analysis of this project will be developed in the subsequent phase of the study.

The number of storage sites and depots is important in a country with a surface area of 160,000 km^2. With 22 storage sites and 50 depots (most storage sites shelter the depots of two or three oil companies) the country is seemingly fairly well covered. However, the **geographical repartition of the storage sites**, inherited from the pre-independence marketing structure, may no longer reflect the current and future needs of the country. While the density of storage sites is particularly high in the East and Northeast, vast areas in the North and the Southwest remain supplied by depots located several hours away from a depot, which does not optimize the integrated delivery system.

All depots are far from being able to store (hence, to sell) the **complete range of products**. Indeed, only diesel is available at every single storage site, and kerosene can be found almost everywhere. Conversely, regular gasoline is not available at many locations, including Ashuganj, Bhairab and most depots in the Northwest. Premium gasoline is not stored in those sites where regular gasoline is not available, as well as in additional locations such as Barisal and Jhalakati. Fuel oil is absent almost everywhere, except in the Dhaka and Khulna areas.

Finally, Bangladesh lacks **emergency storage**. The EPOL (where 'E' stands for Emergency) facility has a mere 3,500 tons storage capacity, and is actually mainly used by the Military. Bangladesh needs to design and implement an efficient emergency storage policy. As per National Energy Policy, the strategic stock of petroleum products is to be 60 days consumption spread all over the country.

3. Non technical issues

The **distribution margins** constitute the original stream of revenues of the oil companies. Their level is fixed by the government; the oil companies have no bearing whatsoever on them. Margins have been historically set at a low level to maintain low prices of oil products, thus transferring the responsibility of the social policy wanted by the government onto the oil companies. The same goes for **railways transport tariffs**, which have also been set at low levels and have not been adjusted for years, thus depriving BR from the resources required to develop transport supply.

A major consequence is that the oil companies are not financially capable of initiating and implementing an **investment policy** of their own. Developing and improving infrastructure to meet the growing requirements of the industry currently implies for the companies to go through complex and lengthy **investment procedures** in order to have access to

Government money, which severely constrains their ability to be responsive to new challenges and strongly hampers their operating efficiency.

Another perverse effect of maintaining low margins is that the oil companies can only survive by **developing in newly opened markets**, e.g. lubricants, where they have proved fairly successful, in particular in the upper tier lubes market. While market opening and competition are certainly an efficient and desirable way for oil companies to diversify their business, it is not economically healthy to institutionalize within a same company a system whereby a purely commercial, profit-making activity heavily cross-subsidizes a strategic, but loss-making activity. The risk is dual: on the one hand the more profitable activity may draw all attention and resources from the company's management and leave the less profitable activity just bare-bone; on the other hand the non profitable activity becomes highly dependent on the results of the commercial activity, hence very vulnerable to any downturn of that activity. Oil companies should be given **sustainable, appropriate resources** that be genuinely generated by the operation of their strategic activity, i.e. the marketing and distribution of *all* oil products.

CHAPTER 1: SUPPLY SYSTEM OVERVIEW

1. Governing conditions

As is the case in many logistics operations, marketing and distributing oil products in Bangladesh is heavily dependent on “hard” conditions, which shape the operation of the oil companies.

1.1. Geography

Bangladesh lies at the apex of the Bay of Bengal and has rivers that come down from the surrounding countries and flow through it. Nearly the whole area of the country consists of low and plain lands and about 7% of its surface is covered by a dense 24,000-km long network of inland waterways. Three major river systems (the Jamuna, the Meghna and the Padma, which gave their names to the three state-owned oil marketing and distribution companies) and their confluence form the world's largest delta here. As a result Bangladesh has about 9,000 km^2 of territorial waters with a 720-km long coast line.

The complex river delta

(Meghna to the northeast, Jamuna to the north, Padma to the northwest)

The main hilly area consists of the Chittagong Hill tracts to the southeast of the country. The highest point in Bangladesh is in Mowdok range at 1,052 m. The second main consequence of the physical patterns is that there is only one harbour site, Chittagong, that offers appropriate deep water conditions.

About two-thirds of the land is vulnerable to flooding. Most parts of Bangladesh are less than 12 m above the sea level, and it is believed that about 10% of the land would be flooded if the sea level were to rise by 1 m. As a result, costs of development and maintenance of transport infrastructure are high. On the other hand, inland water transport has always been a natural and relatively cheap means of transport in Bangladesh. In certain areas, it remains the only mode of transport available to carry passengers and goods alike.

1.2. Climate

Straddling the Tropic of Cancer, Bangladeshi climate is tropical with a warm, dry winter from November to April (the Rabi season), a hot, humid summer from May to October (the Kharif season). A warm and humid monsoon season lasts from June to October and supplies about 80% of the country's rainfall. Natural calamities, such as floods, tropical cyclones, tornadoes, and tidal bores—destructive waves or floods caused by flood tides rushing up estuaries—ravage the country, particularly the coastal belt, almost every year with the effects of deforestation, soil degradation and erosion. The cyclones of 1970 and 1991 were particularly devastating, with the cyclone that struck Bangladesh in 1991 killed some 140,000 people.

During the annual monsoon period, the rivers of Bangladesh flow at about 140,000 cubic meters per second, but during the dry period they diminish to 7,000 cubic meters per second. Because water is so vital to agriculture, more than 60 % of the net arable land is cultivated in the rainy season despite the possibility of severe flooding, and 40 % of the arable land (about 40,000 km^2) is cultivated during the dry winter months

Major water control projects have been developed responded to this "dual water regime" by providing flood protection, drainage to prevent over-flooding and water-logging, and irrigation facilities for the expansion of winter cultivation.

The climatic conditions have significant consequences on the organisation of the distribution of oil products, in particular during the 5-month long dry season:

- Shallow waters reduce dramatically the water draft in many rivers and increase river siltation, thus making it more difficult for water transport to satisfactorily supply the oil depots,
- Irrigation needs increase the use of pumping devices, in particular in the widely irrigated agricultural land of Northwestern Bangladesh.

1.3. History

As far as logistics is concerned, history has had a particular bearing on the design of the railways network. Bangladesh inherited from the former British Empire a railway network that had been tailored to the needs of a much larger, unified territory. The Bangladesh Railways (BR) of nowadays were then an integral part of the dense and efficient railway grid of India. This explains why two types of networks co-exist in a rather small territory (at least, compared with India).

While the broad gauge (BG) portion, in the west of Bangladesh, was a part of the main Indian railway network centered on its eastern hub at Calcutta/Howrah, the meter gauge (MG) portion was mainly dedicated to connect the northeastern states of India with the port of

Chittagong. Both systems were designed to run along north-south corridors. They were operated in parallel and had not been meant to ever be inter-connected. Dhaka was only connected to Chittagong by a dedicated dead-end line branching off the main north-south MG line.

When Bangladesh gained independence from India, first as the eastern province of Pakistan, then as a State, the railways network did not suit the needs of the new country. The country's main economic and political centers were not connected by the shortest route, and often not connected at all. There was no bridge over the Jamuna river. Traveling between Dhaka and Khulna, the country's third city, would require to cross the Jamuna by ferry until the Jamuna Bridge was opened in 1998.

A second responsibility of History is that Bangladesh shares with India the same physical territory – in geographical terms – constituted by the immense river delta system of the Jamuna [Brahmaputra]--Padma [Ganges] rivers. Bangladesh has 57 trans-boundary rivers, making water issues politically complicated to resolve – in most cases as the lower riparian state to India. One the issues Bangladesh is facing is the adverse consequence of the Farakka dam on the flow rate of the Padma, in particular during the dry season – in addition to other key problems such as salinity levels, contaminated fisheries, and water quality[2].

2. The supply system

The supply of oil products to consumers comprises of five main components:

- Production
- Reception and main storage
- Regional depots
- Transport from the main storage to regional depots
- Retail distribution

2.1. Production

From the logistics chain standpoint, the "production" component includes the transformation of crude oil into oil products at the ERL refinery, as well as the imports of refined products from the international market. These aspects are dealt with in the "Refinery" part of the study.

2.2. Reception and Main Storage

At the beginning of the distribution chain the oil products are handled at the main storage facilities operated by the three oil marketing companies in Chittagong, called "Main installations" (MI). The three tank farms are located along the Karnaphuli river, in the vicinity of the refinery. Refined products produced at the ERL are transported by pipeline from the

[2] The Farraka barrage was built by India to divert the Ganges River water into the Hooghly River during the dry season, in order to flush out the accumulating silt, which in the 1950s and 1960s was a problem at the major port of Kolkata on the Hooghly River.

refinery's storage tanks to the main installations, while imported products are unloaded at the jetties of each MI[3]. Seagoing vessels carrying about 100,000 tons per parcel, which requires lightering onto smaller vessels of about 12,500 tons. Refined products are transported by mid-size vessels (cargoes of 30,000 to 35,000 tons), which requires small quantity / no lightering.

2.3. Regional Sales and Depots

BPC has recorded total sales of 3.76 million tons in FY2009-2010. Out of this total, 3.64 (over 97%) deal with the main six products (regular and premium gasoline, diesel, kerosene, jet fuel, fuel oil). All the products are usually marketed through the regional depots of the three oil companies, including the main installations at Chittagong that play the role of both a regional depot for local sales, and dispatch centre to the other depots --- as do some other depots.

Outside the Chittagong's MI there are 22 storage sites, gathering 50 company depots in total as most storage locations are home to two or three depots.

The location and the general configuration of the depots have been inherited from the previous operators that were handling them before Independence. Their characteristics depend to a large extent on the conditions that were prevailing forty years ago, in particular in terms of access – water or railway.

2.4. Transport from the Main Installations to Regional Depots

As far as the main six products are concerned, (premium and regular gasoline, diesel oil, kerosene, jet fuel and fuel oil) the Chittagong main installations of the three oil companies (POCL, MPL, and JOCL) are the only 'concentration' point in Bangladesh[4]. Hence, every single ton of product that is sent out to the regional depots (or to some large consumers that are equipped with their own storage) leaves from the MI.

Due to the physical and historical constraints briefly mentioned in Section 1.1 above, the transportation system is fairly complex. Except airport depots, all depots are supplied by either marine tankers or rail tankers, the former accounting for an overwhelming 93% of the volumes dispatched from the MI. Transportation means include two types of marine tankers ('coastal tankers' and 'shallow draft tankers') and two types of rail tankers (broad gauge wagons and meter gauge wagons).

Depots are supplied by either water or rail, or a combination of both modes. There are in total 23 different regular supply routes, complemented by non regular, ad hoc routes where required, for instance to match additional demand during the high demand, dry season. Some depots, such as Parbotipur, are served on a permanent basis by two different routes, depending on the products transported. Half the supply routes require that products be transferred at mid-point from one transportation means onto another.

The regular range of transportation routes includes five different combinations:

- Coastal tankers only, e.g. to Godnail, Fatullah, Daulatpur, etc
- Coastal tankers + transfer onto shallow draft tankers, e.g. to Baghabari, Sachna Bazar, etc.

[3] Imported premium gasoline and some diesel are received at ERL.
[4] With two exceptions: the fuel oil that supplies the KPCL power plant in Khulna, and the production of the gas plants in the Sylhet area.

- Coastal tankers + broad gauge railway, e.g. to Parbotipur, Rajshahi, etc.
- Meter gauge railway only, e.g. to Sylhet, Rangpur, etc.
- Coastal tanker + road tanker, only to KAD (Dhaka airport depot).

In addition, according to the demand or weather conditions, some unconventional routes may be operated, such as few shallow draft tankers (having Bay crossing capabilities) all the way from Chittagong to Baghabari.

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2.5. Retail distribution

Retail distribution is done by four types of retailers, under contract with each marketing company. This includes:

- Filling stations
- Agents / Distributors
- Packed point dealers, and
- Barge retailers.

In addition, each company operates a portfolio of direct, bulk customers.

Figure 1.1 - Routes System from MI-Chittagong to Regional Depots

	RECEIVING TERMINAL			TRANSPORTATION ROUTE			
	Code depot	Depot(s) operated by	Type of depot	Origin	Route and Distance (first leg)	Transfer point	Route and Distance (2nd leg)
FROM CHITTAGONG (MI) TO:	MI						
CHITTAGONG AREA							
Chittagong Airport Depot	CTG AP	Padma	Apt depot	MI	10 km		
DHAKA AREA							
Godnail	**GOD**	PAD, MEG	Tanks	MI	335 km		
Fatullah	**FAT**	MEG, JAM	Tanks	MI	335 km		
Airport ("KAD")	KAD	Padma	Apt depot	MI	to Godnail	GOD	40 km
EPOL (emergency depot)	EPO	Meghna	Emergency	MI	335 km		
Chandpur	**CHA**	All 3	Tanks	MI	276 km		
Ashuganj	**ASH**	Padma	Tanks	MI	to Godnail/Fatullah	GOD/FAT	
Bhairab Bazar	**BBZ**	All 3	Tanks	MI			
SOUTHWEST AND NORTHWEST AREAS							
Daulatpur (Khulna)	**DLP**	All 3	Tanks	MI	490 km		
Natore	**NAT**	No storage	direct transfer	MI	to Daulatpur	DLP	279 km
Harian	**HAR**	No storage	direct transfer	MI	to Daulatpur	DLP	295 km
Rajsahi	**RAJ**	No storage	direct transfer	MI	to Daulatpur	DLP	303 km
Parbotipur	**PAR**	All 3	Tanks	MI	to Daulatpur	DLP	419 km
				MI		761 km	
Rangpur	**RGP**	All 3	Tanks	MI		800 km	
Balashi	**BLS**	MEG	Barge	MI	to Fatullah	FAT	352 km fm FAT
Chilmari	**CHL**	JAM, MEG	Barge	MI	to Godnail/Fatullah	GOD/FAT	438 km fm FAT
Baghbari	**BGB**	All 3	Tanks	MI	to Godnail/Fatullah	GOD/FAT	220 km fm FAT
Barisal	**BSL**	All 3	Tanks	MI	263 km		
Jhalkati	**JHL**	All 3	Tanks	MI	298 km		
NORTHEAST AREA							
Sylhet	**SYL**	JAM, PAD	Tanks	MI	381 km		
Srimongal	**SMG**	All 3	Tanks	MI	294 km		
Mogla Bazar	MBZ	MEG	Tanks	MI	370 km		
Brahman Baria	**BBA**	MEG, PAD	Tanks	MI	from local gas plant		
Sachna Bazar (Chattak)	**SBZ**	JAM	Barge	MI	to Fatullah	FAT	298 km fm FAT

CHAPTER 2: MARKET ASSESSMENT

1. Oil demand in FY2009-2010

This section presents an overview of the main characteristics of the oil products market, as it can be observed now, as well as a brief review of its evolution over the recent past.

The current situation, i.e. total country consumption for the financial year FY 2009-10 (BPC sales together plus private sector sales / consumption), constitutes the basis for the projections of the oil demand that are analyzed and presented in section 2.2 below.

The FY2009-10 figures presented here are the latest values available to us. Figures were collected from BPC and its subsidiary companies (all are not yet validated), estimated figures were taken for the four products where private sector is involved. Any discrepancy, if detected, will presumably be corrected in the course of finalisation of this report.

1.1. Overall Consumption in FY2009-2010

The BPC Group, through its three marketing companies (Jamuna Oil, Meghna Oil, Padma Oil) and LPGL[5], is responsible for over 93% of the distribution and marketing of the oil products. The balance comprises of the volumes of the three liberalized products[6] marketed by private operators and the fuel oil directly procured by KPCL for their power station in Khulna.

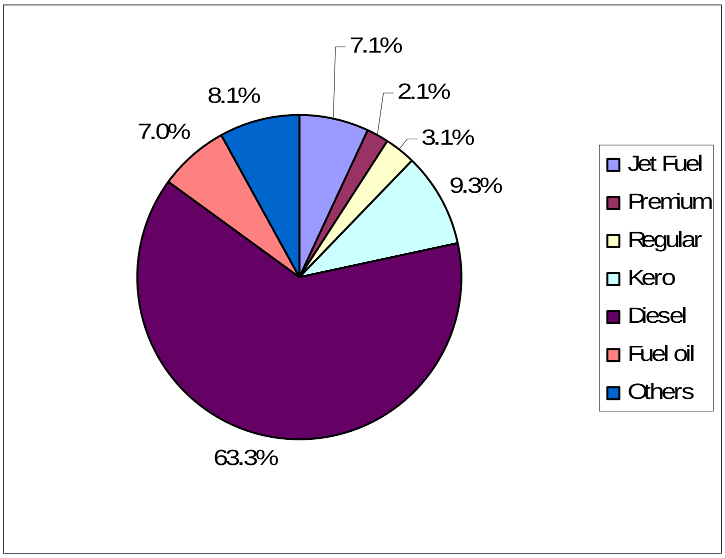
The overall consumption of oil products (‘POL’) has slightly exceeded the 4 millions ton mark in FY2009-2010, for the first time in Bangladesh’s energy history.

[5] LPG Ltd operates the Group’s bottling plants and sends the LPG bottles to the three marketing companies.
[6] LPG, lubricants and bitumen.

Table and Figure 2.1 - Consumption of Oil Products, FY2009-2010

Oil Products	Consumption (tons)	Share (%)
Jet Fuel (Jet A-1)	286,900	7.1%
Premium (HOBC)	85,500	2.1%
Regular (MS)	127,200	3.1%
Kerosene (SKO)	376,600	9.3%
Diesel (HSD)	2,568,200	63.3%
Fuel oil (FO, FOHS)	285,700	7.0%
Jute Batching oil (JBO)	19,100	0.5%
Lubricants	60,900	1.5%
LPG	81,600	2.0%
Bitumen	159,700	3.9%
Spirits	7,000	0.2%
TOTAL	**4,051,400**	**100.0%**

Sources: BPC, private operators (LPG, bitumen and lubricants), own estimate (fuel oil)



The table and the graph above show the much imbalanced pattern of the oil consumption in Bangladesh:

- With over 3.2 million tons, middle distillates (diesel oil, kerosene and jet fuel) account for 80% of the total consumption. The 2.6 million tons of diesel oil represent by far the lion's share, at over 63% of the overall demand;
- At the other end of the products range, the consumption of light automotive products (regular and premium gasoline) remains very thin and accounts for only 5.2% of the total;

- The consumption of heavy fuel oil (furnace oil) does not exceed that of jet fuel, with less than 300,000 tons and 7% each of the total consumption;
- The other products (lubricants, LPG, jute batching oil, bitumen and various spirits) account for about 8%;
- Light naphtha is produced by the ERL refinery, but all volumes (around 100,000 tons per year) are exported for lack of domestic market.

1.2. Recent trends

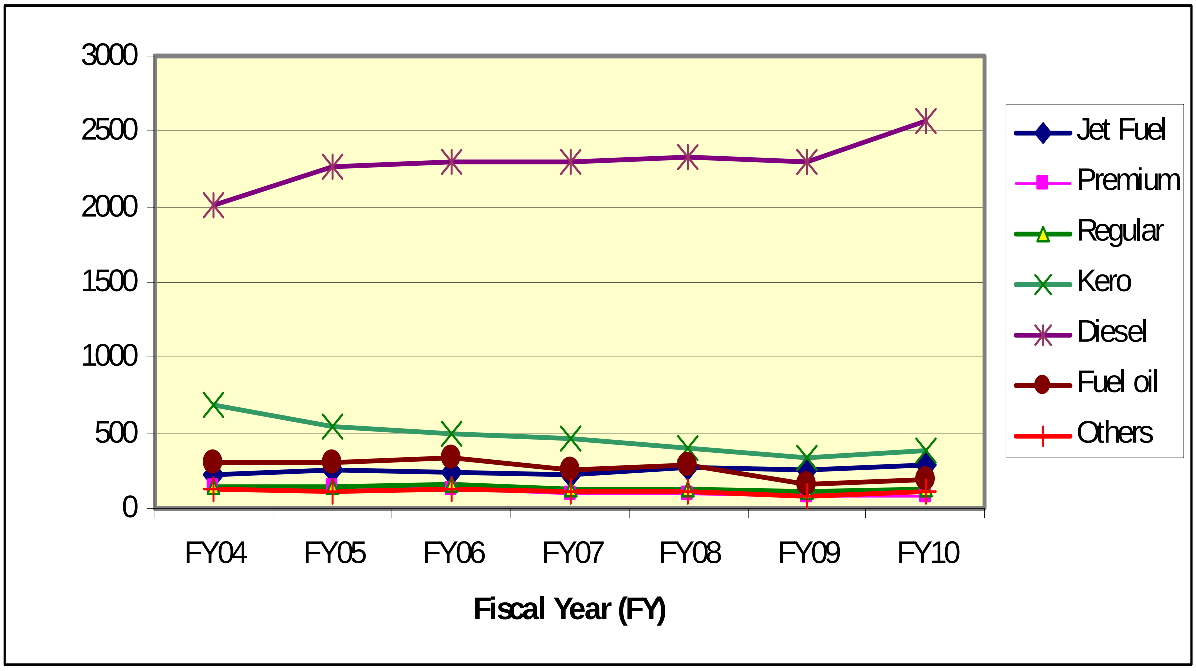
The overall consumption of oil products has remained roughly stable over the recent years. The consumption has only increased by 200,000 tons between FY2004 and FY2009-2010, i.e. at a moderate growth rate of 0.9 % per annum in average. There are two likely explanations of such a low growth rate: the development of natural gas until very recently, in spite of the threats over the future productivity of the fields, and the fact that operators driven by the gas crunch to limit their growth or even downscale their activity (in particular power generation and industry) have not yet shifted to oil products due to technical and/or financial constraints.

Table and Figure 2.2 - Recent Evolution of the Oil Products Sales by BPC[7]

Thousand tons	FY2003 -04	FY2004 -05	FY2005 -06	FY2006 -07	FY2007 -08	FY2008 -09	FY2009 -10	*Average Yearly Variation*
Jet Fuel	227	254	239	226	277	254	287	*4.4%*
Premium	146	143	126	95	90	78	86	*-6.8%*
Regular	151	144	153	130	125	115	127	*-2.6%*
Kerosene	694	545	499	462	405	343	377	*-7.6%*
Diesel	2,004	2,265	2,299	2,294	2,334	2,301	2,568	*4.7%*
Fuel oil	309	310	333	256	290	164	194	*-6.2%*
Others	126	108	132	111	106	77	118	*-1.1%*
TOTAL	**3,657**	**3,768**	**3,782**	**3,574**	**3,626**	**3,326**	**3,757**	*0.5%*

Source: BPC

[7] Supplies from the BPC group + fuel oil for KPCL. Does not include the supply from the private marketers of lubricants, LPG and bitumen.



Within the overall evolution, however, several products have recorded opposite variations:

- As is the case in most developing economies, the share of diesel oil is increasing due to the development of road transportation combined with increased demand for agriculture and power generation;
- The second factor that has contributed to reduce the demand of motor fuels is the development of CNG, which competes primarily in the gasoline market;
- As a result, the consumption of light motor fuels (regular and premium gasoline) is decreasing, both in volumes and percentage. The decrease particularly hits the sales of premium gasoline (- 41% in 6 years), although smaller size cars keep on running, to a large extent, on regular gasoline. It should be noted that, following the strong decrease recorded in FY2008-09, the demand for gasoline has increased again in FY2009-10, a trend confirmed in the first months of FY2010-11.
- Kerosene, a domestic fuel used primarily in rural areas and poorer urban districts, records a sustained and dramatic fall generated by the development of electricity and, albeit to a lesser extent, by the parallel development of natural gas networks in some large cities such as Dhaka. Its increased price is also considered as a factor in this regard.

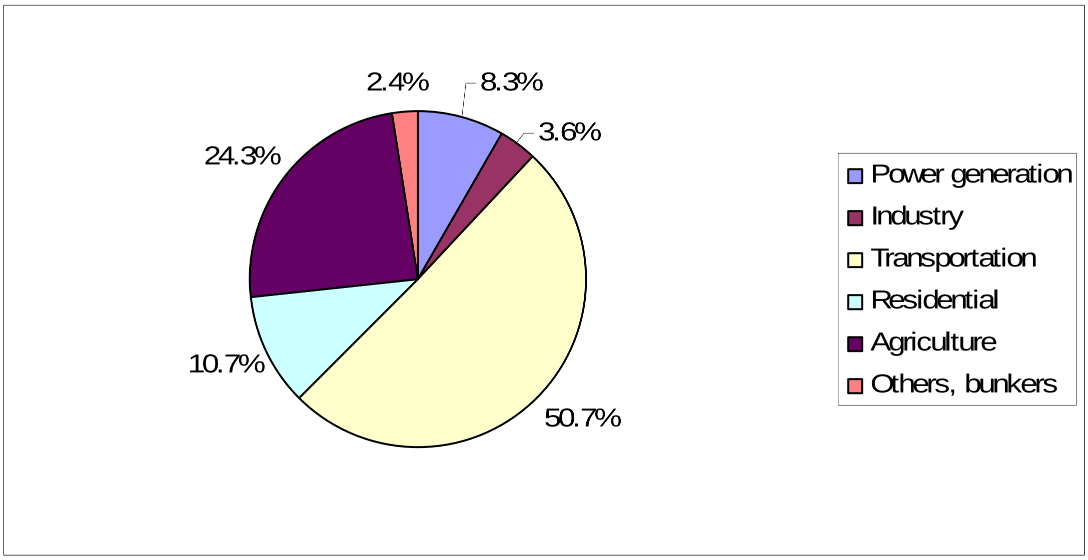
1.3. Sectoral Breakdown

The table and chart hereunder show the sectoral breakdown of the main six fuels marketed by the BPC group in FY2009-2010, plus the fuel oil directly procured by KPCL. The main utilisation sectors include power generation, industry, transportation, residential & commercial, agriculture, and others, which includes, inter alia, marine bunker fuels.

Table and Figure 2.3 - Sectoral Breakdown of Oil Products Consumption, FY2009-2010

	Consumption (tons)	Share (%)
Power generation	307,830	8.2%
Industry	133,370	3.6%
Transportation	1,892,990	50.7%
Residential	399,320	10.7%
Agriculture	906,850	24.3%
Others, bunkers	89,740	2.5%
TOTAL	**3,730,100**	**100.0%**

Source: BPC figures; own estimate (HFO)



With close to 1.9 million tons, the transportation sector is by far the largest consuming sector, which accounts for slightly over half the oil products consumption. Almost all fuel types are involved, except domestic kerosene. Within the sector, diesel oil accounts for 73%, jet fuel 15%, and light motor fuels 11%.

Agriculture ranks second, with just over 900,000 tons, most of the consumption being in the form of diesel oil. A large proportion of diesel is used to activate irrigation pumps during the dry season, which causes significant variations of the demand across the year (the ‘seasonal swing’).

The residential sector (400,000 tons) consumes mostly kerosene, with a much thinner consumption of diesel oil. Those two fuels are increasingly complemented by LPG, which already represent about 81,600 tons.

With 307,800 tons and 133,400 tons respectively, the volumes consumed by the power and industrial sectors are very small. The most widely used fuel to run boilers and other industrial equipment remains, by far and large, natural gas. Indeed, most liquid fuels are just used whenever gas is not available, i.e. in the western districts of the country, and also to run emergency power generators during power outages. However, the consumption pattern of the power generation sector is evolving rapidly due to the gas crunch.

The table hereunder presents the matrix of the product-wise X sector-wise consumption:

Table 2.4 – Sectoral Country Consumption Matrix, FY2009-2010

Metric tons			Gasoline				
	HFO	Diesel	Premium	Regular	Kerosene	Jet fuel	TOTAL
Power generation	136,720	171,110					307,830
Industry	67,160	66,210					133,370
Transportation	6,540	1,386,850	85,500	127,200		286,900	1,892,990
Residential		22,720			376,600		399,320
Agriculture		906,850					906,850
Others, bunkers	75,280	14,460					89,740
TOTAL	285,700	2,568,200	85,500	127,200	376,600	286,900	**3,730,100**

Source: BPC figures; own estimate (HFO for power generation)

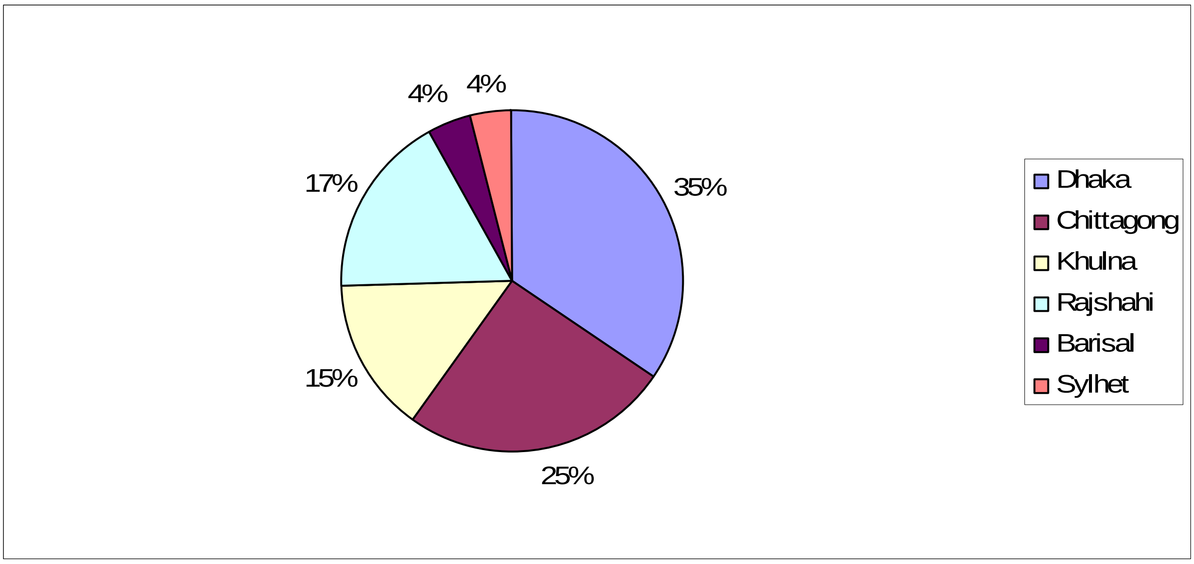
1.4. Regional Breakdown

It comes as no surprise that the capital city is by far the major oil consuming area, in spite of being heavily gasified – a phenomenon that can be observed in most emerging economies. With about 1.3 million tons the Dhaka and its surroundings concentrates 36% of the oil products marketed by the BPC group in FY2009-10. The Chittagong division ranks second, with 22%, followed by the populated, albeit less urbanised western divisions of Khulna and Rajshahi (between 14.5% and 17.5%), where natural gas is virtually absent. Finally, the smaller districts of Barisal and Sylhet (the latter is heavily gasified) account for 4% each.

Table and Figure 2.5 - BPC Regional Sales, per Division (FY2009-10)

Divisions	Consumption (tons)	*Share (%)*
Dhaka	1,293,036	*34.4%*
Chittagong	954,809	*25.4%*
Khulna	547,186	*14.6%*
Rajshahi	657,395	*17.5%*
Barisal	156,232	*4.2%*
Sylhet	148,632	*4.0%*
TOTAL	3,757,290	*100.0%*

Source: BPC



1.5. Market Opening

This section briefly describes the recent evolution in terms of market structure. The larger share of the consumption is supplied by BPC. Until recently, BPC was holding a monopoly for the production, imports, storage, and marketing of oil products, either directly or through the refinery and its marketing subsidiaries.

However, the commercial structure of the marketing of oil products has evolved over the past few years. The main six products, in terms of volumes sold, are still marketed by the sole BPC group. This is the case of the light products, such as the automotive fuels (regular and premium gasoline), the middle distillates (jet fuel, diesel oil, kerosene), and the heavy fuel oil. However, the Khulna Power Corp. Ltd (KPCL) benefits from a derogation granted by BPC to procure in the international market the 90,000 tons or so of heavy fuel oil required for the operation of their power station in Daulatpur near Khulna.

Three other products (LPG, bitumen and lubricants) are now marketed in parallel by both the BPC group and private operators. Indeed, BPC only markets the volumes produced inside the group by the refinery and the Kailashtila gas plant, while the private operators procure all the products they market from the international market.

2. Oil demand projections

2.1. Modeling

There is no, to the best of our knowledge, official or validated long term projections of the oil demand in Bangladesh. The Marketing Division of BPC establishes short-term projections of the demand to prepare the oil procurement programmes, generally under Government to Government (G to G) agreements. The Marketing Division initially revised their demand projection up to FY 2011-12 covering the heavy demand of diesel and fuel oil for new power plants caused by the natural gas crunch and energy crisis. BPC has very recently prepared demand projections up to FY 2014-15 totaling their sale of 6.65 million MT during that year. Long term projections made in earlier studies are no longer valid due to high demand of oil products for the new power plants.

Against that background, we have designed a model to evaluate the long term demand of oil products. The model focuses on the demand, whatever the source of supply (local production or imports). It constitutes one of the elements that will be used by the team in charge of the refinery component of the study to optimize the size of the future facility.

Experience shows that simply extending towards the future historical trends prove far from being sufficient and enough reliable to assess long term projections, in particular in emerging economies The model is thus based on both the analysis of the current and past situation (for the historical trends), and the reference to macro-economic indicators (for the future trends).

The model uses as baseline data the country consumption data including private sector recorded for FY2009-10[8], the average evolution of the consumption observed in a given sector or activity over the last 10 to 15 years (depending on the available sources of information), in relation to the macro-economic indicators. These indicators are the real GDP[9] growth rates (both overall and sectoral) and the demographic growth rate.

The projections are made at two levels: by products and by consumption sectors. Product-wise, we have considered those main six products that accounted (in FY2009-2010) for nearly 94% of the overall country demand, i.e.:

- heavy fuel oil ('furnace oil', or FO),

[8] Released in October 2010
[9] i.e. at constant prices.

- diesel oil (HSD),
- regular gasoline (‘motor spirit’, or MS),
- premium gasoline (‘octane’, or HOBC),
- kerosene (SKO),
- jet fuel (jet A-1).

The consumption sectors or consumer classes are those in use in PBC operations and statistics, i.e.:

- Power generation,
- Industry,
- Transportation,
- Residential,
- Agriculture,
- Others.

For each product in each sector we have assessed specific growth rates for three successive periods:

- Short-medium term (2011-2015)
- Medium-long term (2016-2020)
- Long term (2021-2030)

…so as to constitute three products X sectors matrices, one for each period.

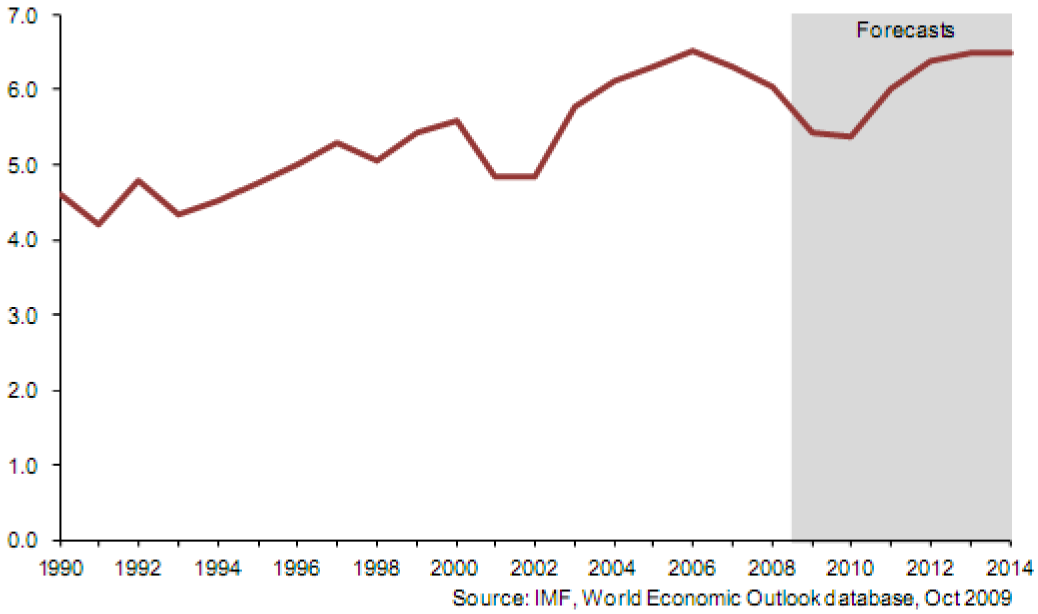
2.2. GDP Growth Rate

Bangladesh has experienced unbroken economic growth since at least 1980, despite the natural disasters that the country has suffered during that time. Over the 1995-2008 period the overall GDP (in real terms) has increased at a growth rate of 5.6 %[10], with only limited variations around this average value. The 1995-2001 years have recorded a slightly lower rate, around 5-5.5 %, followed by a slump in 2002-2003, which dragged the economic growth below 5 %. The second half of the 2000s saw a fairly sustained recovery, with growth rates clearly above 6 % p.a., except in 2009.

The IMF’s October 2009 forecast (see figure 2.6 below) suggested that Bangladesh would maintain this average growth rate from 2009-2014, despite a fall in growth to 5.4% in 2009 and 2010 due to the economic crisis, which has led to the contraction of the garment exports market and reduced remittances from expatriated Bangladeshis. Such rate matches the recent ADB’s forecast of 5.5 % in FY2009-2010. More recent forecast from the IMF, however, suggests that the GDP growth will increase next year and stabilize at 6 % in FY2011-2012, then increase slightly to 6.15 % in FY2013.

[10] Historical GDP figures come from the IMF and the website of Tradingeconomics, which quotes figures from the World Bank and the IMF.

Figure 2.6 - Overall GDP Growth Rates, actual and forecast, FY1990-2014

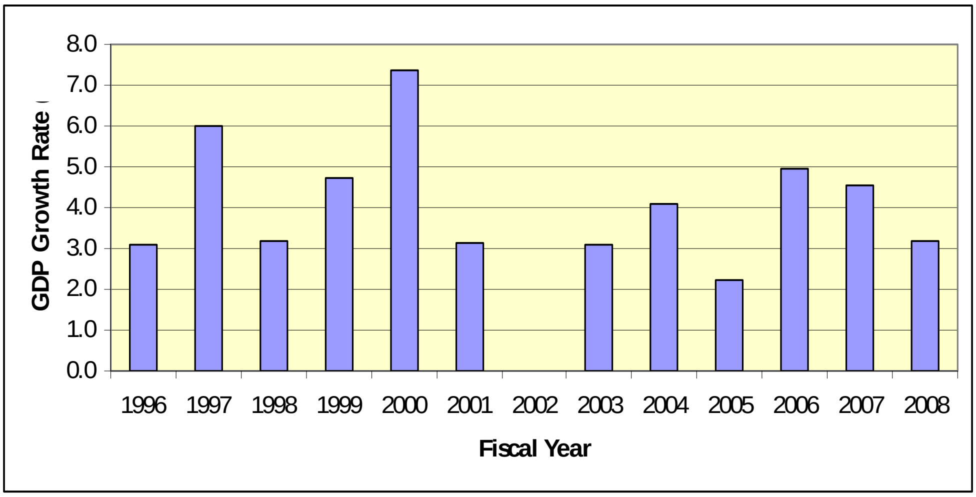


Based on the long standing, fairly stable GDP growth rate over the last 20 years, we have considered a constant 6 % growth rate over the study period.

2.3. Agriculture

Over the 1995-2008 period (latest sectoral GDP figures available), the agricultural sector has grown at a real average rate of 3.6 % p.a. This is 1.8 % less than the overall GDP, which has reached 5.6 % p.a. over the same period.

Figure 2.7 - GDP Growth Rate, Agriculture (FY1996-2008)



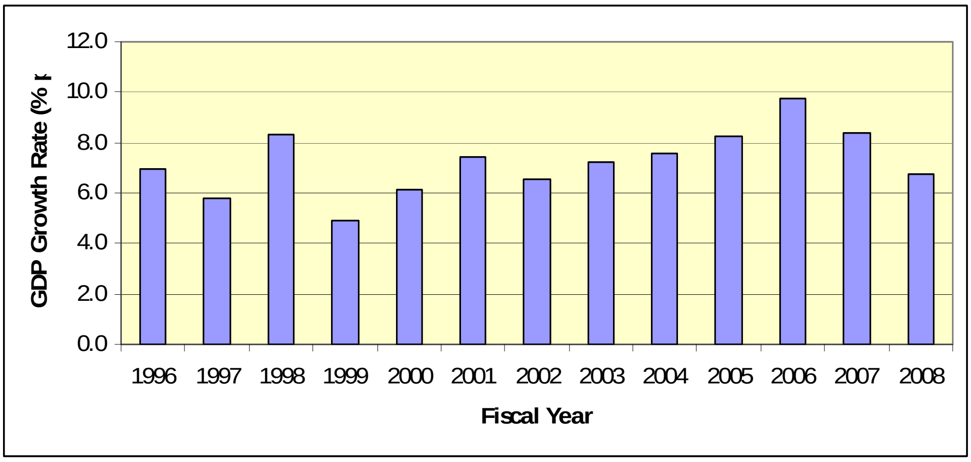
Source of data: BSS

Agriculture uses only diesel oil. We have assessed that the future diesel oil demand of the sector will follow the evolution of the sectoral GDP, i.e. it will show a negative mark up below the overall GDP. In the short term (2011-2015 period), it is assumed that the mark up will be 1.8 percentage point below the forecasted overall GDP, which gives a sectoral GDP growth rate of 4.2 %. For the following periods, we consider that improved efficiency of the equipment will allow to steadily bend the energy requirements (i.e. energy intensity will tend to decrease), leading to a negative mark up of 2 points in 2016-2020, then 2.2 points in 2020-2030. As a result the oil demand is expected to increase by 4 % in 2016-2020, and 3.8 % in 2021-2030.

2.4. Industry

The industrial sector consumes heavy fuel oil and diesel oil, in equal volumes. Over the 1996-2008 reference period, the industrial GDP has increased by 7.2 % p.a. in average, i.e. 1.6 percentage point above the overall GDP.

Figure 2.8 - GDP Growth Rate, Industry (FY1996-2008)



Source of data: BSS

We have considered that the growth rate of the industrial GDP will keep the same mark up of 1.6 point above the overall GDP, all over the study period. However, the energy intensity will decrease due to improving efficiency in the industrial equipment, by 0.2 point during each period. As a result, the oil demand will keep increasing but at a slower rate than the sectoral GDP, reaching 7.4 % p.a. in 2011-2015, 7.2 % p.a. in 2016-2020, and 7 % p.a. in 2021-2030.

2.5. Residential

Among the six oil products analyzed in this section, the residential or households sector consumes mostly kerosene along limited volumes of diesel oil. Kerosene is used for cooking and lighting in those areas where piped gas and/or electricity is not available and by low-income households who cannot afford LPG. As is biomass kerosene plays the role of a fuel ‘by default’, which is called upon when there is no better option available, whether for technical or financial reasons, as is biomass.

Kerosene consumption has dramatically decreased in the last decade (-46 % between FY2004 and FY2009-2010) mainly due to the combined development of both natural gas networks in urban areas and rural electrification conducted by the Rural Electrification Board (REB), its increased price being the other factor.

We have made broad assumptions concerning the further development of electricity and natural gas, in particular:

- The population will grow at the moderate rate observed in the recent years and widely admitted by statistical institutions, i.e. 1.5 % p.a.,
- Gas shortage will lead the gas distribution companies to put a ban on the extension of the residential connections,
- The number of households connected to electricity will double over the 2011-2030 period, from 11.6 to 23.3 million. The electrification rate will reach 59 % in 2030, from 40 % today.
- Kerosene and biomass will share what is left by the other commercial energy operators.

Against these assumptions, the kerosene demand is expected to remain roughly stable until 2020, and to decrease again from 2021 on, albeit at a moderate -1 % p.a.

2.6. Transportation

Transportation requires almost all kinds of liquid fuels: regular and premium gasoline for the automotive traffic; diesel oil for the transportation of goods and passengers (and, increasingly, private cars), railways, and marine transport; and jet A-1 for air transport.

2.6.1. Regular and Premium Gasoline

The sales of regular and premium gasoline have dramatically decreased in the recent past, mostly due to the development of CNG. Sales have recorded negative growth rates of –2.7 % and –6.9 % p.a., respectively for regular and premium, over the FY2004-2010 period. After an all time low in FY2009, caused by the hike of the barrel in the summer 2008 – which hit all transportation fuels, including diesel and jet fuel – the premium and regular gasoline sales have reached back in FY2009-2010 their level of FY2008, with 213,000 tons.

We do not consider that such a rapid decrease will be sustained in the future. On the one hand, gas shortage tends (whether through commercial or regulatory measures) to restrict, and possibly halt, the development of CNG, and even the supply of CNG to gas-run vehicles[11]. On the other hand, Bangladesh should be rapidly concerned by the dieselization of the automotive park, a phenomenon that has already widely impacted emerging as well as industrial economies.

The analysis of the FY2004-2010 period shows that the drop in sales has already begun to slow down, and even to be stopped. In the past three years (FY2007-2010) the sales of regular and premium have kept dropping, but by a much thinner rate, roughly –1 % and –3 % p.a. respectively, than in the previous three years. The sales in FY2009-10 have recovered after the low sales hit in FY2008-09. The sales in the first five months of FY2010-11 tend to confirm that demand is bouncing again, with 97,000 and 137,000 tons of MS and HOBC expected for FY2010-11, respectively.

[11] Such as the closure of CNG filling stations from 3-9 pm, to allow more gas to be available for the evening peak demand from the power stations.

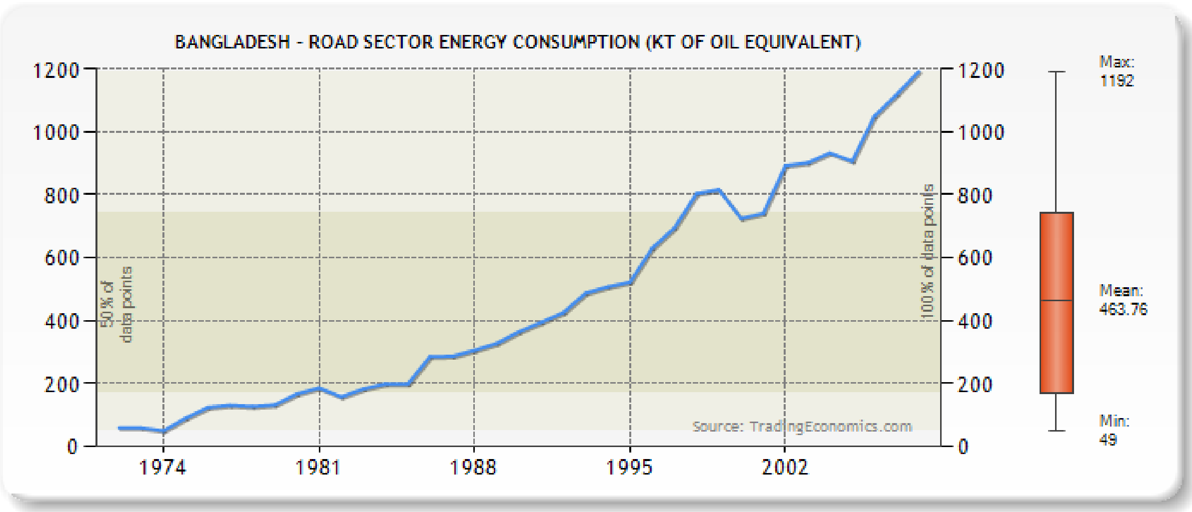
In the short- to medium term (FY2014-15), BPC forecasts 125,000 and 165,000 tons of HOBC and MS, respectively. We have considered a moderate increase in the medium- to long term (4% p.a.), lower than that of GDP, to take into account that (a) the CNG demand is likely to be curbed, but it will not be terminated due to its still much cheaper price, and (b) some dieselization, even id not as massive as in neighbouring countries, will affect the automotive park in the medium-term.

2.6.2. Diesel oil

The transportation sector consumed close to 1.4 million tons diesel oil in FY2009-2010. After adding the gasoline volumes, (0.2 million tons) the sectoral consumption of liquid fuels is estimated at 1.6 million tons.

The graph below shows that the overall consumption by the road sub-sector was 1.2 million tons in FY2008. After deduction of the 200,000 tons of gasoline, this leaves about 1 million tons of diesel.

Figure 2.9 - Consumption of Oil products by the Road Sub-sector

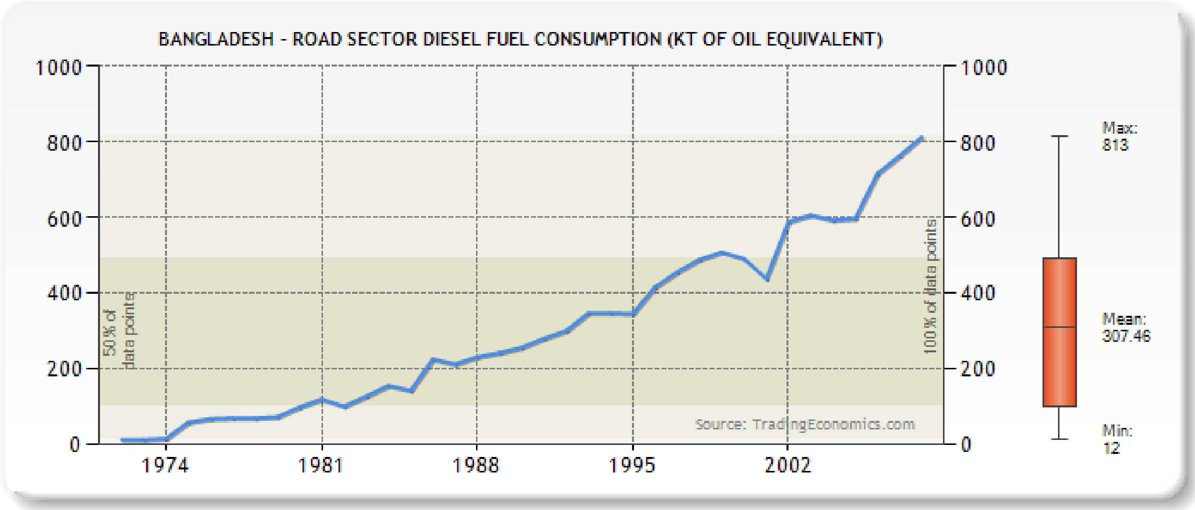


Source: Tradingeconomics

We do not know the detailed breakdown of the diesel consumption into sub-sectors (road transport, private cars, railways, inland water). However, road transport (goods and passengers) accounts for the largest share of the consumption; with 813,000 tons in FY2008; this leaves about 200,000 tons for the consumption of private diesel-run vehicles. The balance (around 0.4 million tons) is presumably consumed by the other surface means of transportation, i.e. railways and marine, although this figure seems high.

The analysis of historical series show that the diesel consumption by the road sub-sector has increased, in average over the FY1996-2008 period, at a rate à 5.7 % p.a., slightly above the GDP growth rate (5.6 % p.a.). This figure seems a bit on the low side as a common trend observed in developing economies is that the transportation requirements, for both goods and passengers, increase at a substantially faster pace than the general economy.

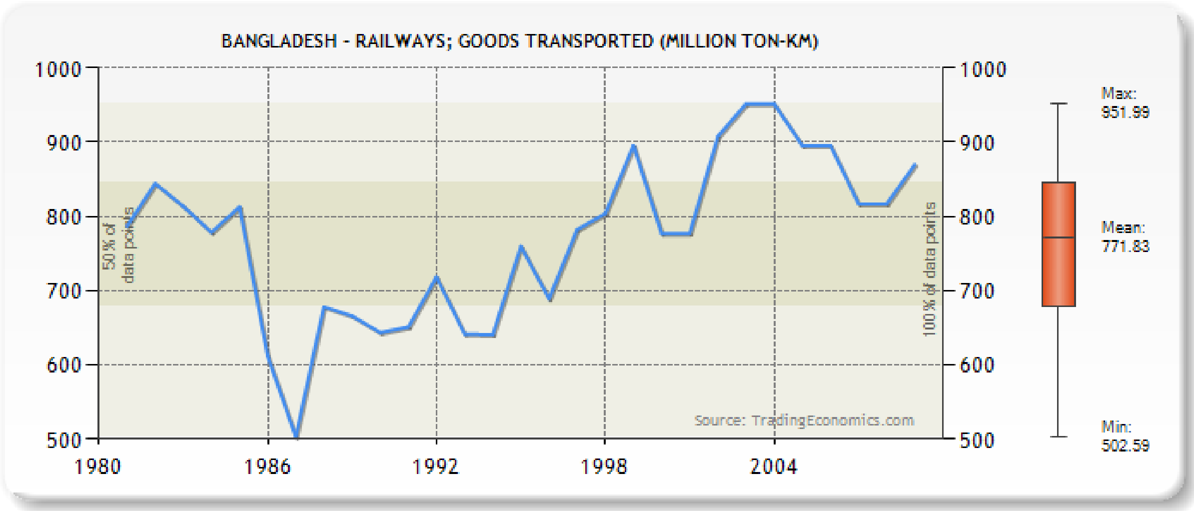
Figure 2.10 - Road Transport Diesel Oil Consumption



Source: Tradingeconomics

Conversely, the consumption of the other surface means of transportation (railways and marine) is not expected to increase substantially. The number of locomotives operated by the Bangladesh Railways has remained about stable over the past 15 years (279 engines in FY1995 vs. 285 engines in FY2008)[12], and the volume of freight has decreased by 12% over the FY2003-2008 five-year period[13]. Domestic marine transportation is reportedly in a similar situation, with the share of the goods transported by boat steadily decreasing, although the number of freight vessels has substantially increased in the previous decade (e.g. +6 % over FY 2002-2006)

Figure 2.11 - Railways Freight transport (million ton-km)



Source: Tradingeconomics

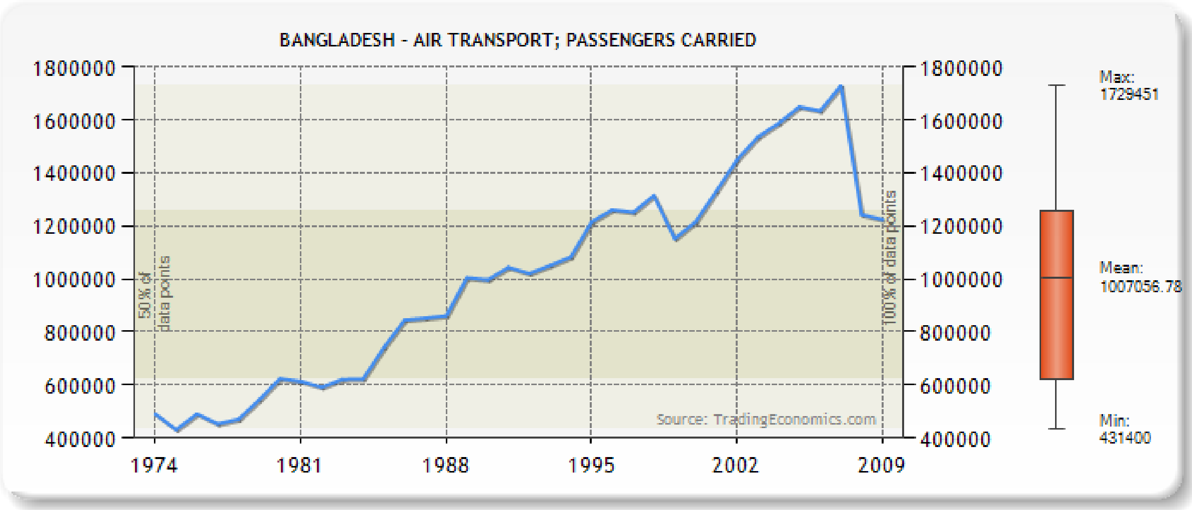
12 Although BR is reported to be procuring 10 broad gauge engines.
13 As quoted by the Bangladesh Bureau of Statistics

We believe that the demand of diesel for transport will keep on growing at a rate consistent with that of the overall GDP. We have considered a rate equal to the GDP growth rate during the first period (FY2011-2015), followed by a moderate decrease that takes into consideration the likely effect of enhanced efficiency in engines and road conditions, leading to GDP –0.2% p.a. over the FY2016-2020 period and GDP –0.4% p.a. over the FY2021-2030 period.

2.6.3. Jet Fuel

The consumption of jet fuel (Jet A-1) is obviously dedicated to air transport[14]. The consumption has reached 286,900 tons in FY2009-2010. With regard to the evolution of the consumption, statistical sources show fairly conflicting figures. Tradingeconomics records a 3% p.a. increase in the number of passengers transported over the FY1995-2007 period, followed by a sharp drop during the following two years, presumably caused by the oil price hike, the recurrent grounding of Biman aircraft and the closure of several destinations to improve the ailing airline's financial situation. Conversely, BPC sales figures do record a limited slow down in FY2009 – as they do for diesel – but show a higher 4.4% p.a. growth rate in the past six years.

Figure 2.12 - Air Passengers Carried



Source: Tradingeconomics

While the two sets of figures cannot be strictly compared (they record carried passengers on one hand, jet fuel consumption on the other), we consider that the BPC statistics reflect more accurately the actual situation of the airline industry and jet fuel consumption in Bangladesh, although the historical series is shorter, hence more subject to error.

We consider a 4.5% p.a. growth rate for jet fuel.

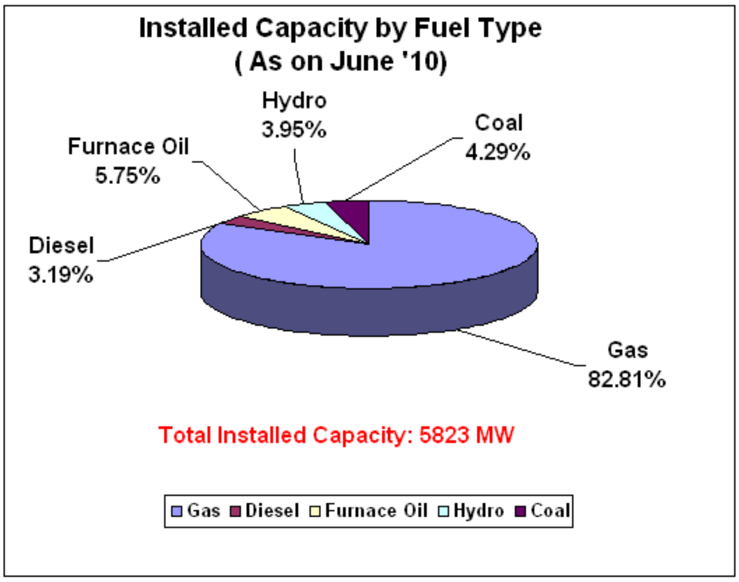
[14] As well as the Bangladeshi Air Force, albeit for limited volumes.

2.7. Power Generation

With close to 83% of the installed capacity, natural gas is by far the leading primary fuel used to generate power. Until recently liquid fuels would only be called upon when gas was not locally available and/or the interconnected grid had not been built. This was in particular the case in the three divisions west of the Jamuna-Padma river system[15] (Rajshahi, Khulna, Barisal), which were home to all diesel- and fuel oil-based power plants.

The picture is now quickly changing, driven by increasingly severe gas shortage. To respond to the growing demand of energy and assist the cash-starving Power Development Board, the Government has permitted private, independent power producers (IPPs) to enter the Bangladeshi market since 1996, through the 15-year, 5-year and 3-year Quick Rental Programmes, which complement PDB's Peaking Plants Programme.

Fig. 2.13 – Installed Capacity by Fuel Type



Source: PDB

2.7.1. Current Situation

At the end of FY2009-2010 there were twelve power plants running on liquid fuels. Six of them are operated by PDB while the remaining six are operated by Independent Power Producers (IPP).

[15] Except the small-size Bola power station in the Barisal Division fed by a local gas field.

Table 2.14 - Liquid Fuels-based Power Plants (as of June 2010)

Power Plants	Operator	De-rated Capacity (MW)	Commissioning Date	Fuel
Khulna Power Station (KPS)	PDB	95	1973, 1984	FO
Bheramara	PDB	54	1976, 1980	HSD
Barisal	PDB	35	1980, 1984, 1987	HSD
Bhola	PDB	4	1988, 2006	HSD
Sayedpur	PDB	19	1987	HSD
Rangpur	PDB	20	1988	HSD
Khulna Power (KPCL)	KPCL	106	1998	FO
Khulna 3-year rental	Aggreko	40	2008	HSD
Thakurgaon		50	2010	HSD
Shikolbaha			2010	FO
Ghorasal		100	2010	HSD
Narayaganj	NEPC[16]		2000	FO
Emirates Power	Emirates		2010	FO
TOTAL		**>523**		

Source: PDB, Power Cell, others

The consumption in FY2009-2010 was 308,000 tons of liquid fuels, including 171,110 tons of diesel oil and 137,000 tons of fuel oil. While all diesel oil was supplied by BPC, the state-owned oil companies supplied 45,120 tons of FO solely to PDB's various power stations, with complementary cargoes sold to KPCL, although the IPP benefits from a derogation from BPC to procure FO directly in the international market[17].

2.7.2. Short and Medium Term Developments (2011-2015)

Short Term: The Quick Rental Programme (QRPP) and Peaking Plants Programme

Realising the urgent need to address the nagging power crisis, the government has undertaken the project to set up within two years (FY2009-2010-2011) a total of 15 QRPPs on a fast track basis without any open tender. This programme is meant to complement the PDB-led Peaking Power Plant Programme, whose lengthier funding and implementation procedures remain within the public sector.

Although policymakers in the Power Ministry recently expressed some frustration over the alleged poor progress in its implementation[18], the quick rental programme seems to now work reasonably well, in spite of the extremely harsh time conditions imposed by PDB – under strong pressure from the Government – on the suppliers. The diesel-run facilities must

[16] New England Power Corp.
[17] The consumption of KPCL has been estimated at 91,600 tons in FY2009-2010.
[18] QRPP Meeting at the Power Ministry, Sept 30, 2010.

be implemented within 120 days from the date of signing the contract, and the FO-run plants within 270 days. Such short periods seem unreasonable and are unlikely to be met. Rental projects commissioned between 2008 and 2010 (mostly gas-run, 40 to 60 MW in average) have been implemented in 15 months in average for rental power stations under the 15-year quick rental programme, and 11 months (ranging from 5 to 21 months) under the 3-year quick rental programme. Such implementation schedules look, from an industry standpoint, quite acceptable and in line with standard practices.

Table 2.15 below presents the short term plan for the 2010-2011 period, including both the Peaking Plants Programme and the 3-year Quick rental Program, broken down into status of ownership, funding programme and fuel type. The implementation of 27 new power stations is included in three components:

- Group A: 9 FO-run power plants under the public Peaking Plants Programme,
- Group B: 11 FO-run power plants under the Quick Rental Programme (IPPs),
- Group C: 7 diesel-run power plants under the Quick Rental Programme (IPPs).

The total installed capacity of the plants to be built within two years reaches 2,047 MW, i.e. two-thirds of the 2010-2015 PSDP programme (see next section).

Table 2.15 - New Liquid Fuels-based Power Plants, April 2010-December 2011

GROUP- A : HFO BASED PUBLIC SECTOR PLANTS				
Power Plant and Location	Capacity	Electricity Production	Expected Commissioning	Monthly Fuel Requirement
	MW	GWh	Date	tons
Faridpur 50 Mw Peaking Power Plant, Faridpur	50	219	Aug.2011	3,818
Dohazari 100 MW Peaking Power Plant, Chittagong	100	438	Aug.2011	7,635
Hathazari 100 MW Peaking Power Plant,Chittagong	100	438	Sept.2011	7,635
Katakhali 50 MW Peaking Power Plant,Rajsahi	50	219	Dec.2011	3,818
Santahar 50 MW Peaking Power Plant	50	219	Dec.2011	3,818
Gopalganj 100 MW Peaking Power Plant,Faridpur	100	438	Aug.2011	7,635
Bera 70 MW Peaking Power Plant, Pabna	70	307	Nov.2011	5,345
Doudkhandi 50 MW Peaking Power Plant, Comilla	50	219	Sept.2011	3,818
Baghabari 50 MW Peaking Power Plant	50	219	Sept.2011	3,818
Sub-total Group A	**620**	**2,716**		**47,340**
GROUP - B : HFO BASED PRIVATE SECTOR PLANTS				
Power Plant and Location	Capacity	Electricity Production	Expected Commissioning	Monthly Fuel Requirement
	MW	GWh	Date	tons
Noapara Quick Rental, Jessore	110	482	Nov.2010	8,399
Barisal Rental,. Barisal	50	219	Dec.2010	3,818
Modonganj Quick Rental	102	447	Mar.2011	7,788
Meghnaghat IEL	100	438	Mar.2011	7,635
Khulna Quick Rental, Khulna	115	504	Mar.2011	8,781
Keraniganj Quick Rental, Dhaka	100	438	Mar.2011	7,635
Meghnaghat Quick Rental	100	438	Mar.2011	7,635
Noapara Quick Rental, Jessore	40	175	Mar.2011	3,054
Julda Quick Rental	100	438	Mar.2011	7,635
Chapai Nowabganj Quick Rental	50	219	Mar.2011	3,818
Katakhali Quick Rental,Rajsahi	50	219	April,2011	3,818
Sub-total Group B	**917**	**4,016**		**70,016**
GROUP - C : DIESEL OIL BASED PRIVATE SECTOR PLANTS				
Power Plant and Location	Capacity	Electricity Production	Expected Commissioning	Monthly Fuel Requirement
	MW	GWh	Date	tons
Bheramara Rental,	110	482	Sept.2010	8,092
Thakurgaon Rental	50	219	July,2010	3,678
Pagla Quick Rental, Narayanganj	50	219	Oct.2010	3,678
Khulna Quick Rental, Khulna	55	241	July,2010	4,046
Ghorashal Quick Rental	45	197	July,2010	3,311
Ghorashal Quick Rental	100	438	Aug.2010	7,357
Siddirganj Quick Rental	100	438	Nov.2010	7,357
Sub-total Group C	**510**	**2,234**		**37,519**
TOTAL 3 GROUPS	**2,047**	**8,966**		**154,875**
Fuel Oil	***1,537***	***6,732***		***117,356***
Diesel	***510***	***2,234***		***37,519***

Source: PDB

The yearly demand of the 20 FO-run power plants will reach 1.4 million tons, and the demand of the 7 diesel-run plants will be 450,000 tons, i.e. 916 and 887 ton per year, respectively, per MW of installed capacity. The main characteristics provided by BPD let understand that the plants are conventional engines working on half-load (4,380 hours per year), with a thermal efficiency of 40%.

Fifteen contracts had been awarded, as of end-September. The sponsor firms, which were awarded the contracts, are:

Table 2.16 - Quick Rental Program: Contracts Awarded as of End-September 2010

Sponsors	Plant Location	Capacity (MW)
Aggreko	Ghorasal (2 plants)	145
Desh Energy	Siddhirganj	100
Power Mutiara	Keraniganj	100
IEL Consortium	Meghnaghat	100
Khan Jahan Ali Power	Noapara	40
Summit Power	Madanganj	102
KPCL	Khulna	115
Hyperion Power	Meghnaghat	100
Dutch Bangla Power	Siddhirganj	100
Acorn Infrastructure	Juldia (Chittagong)	100
Sinha Power	Chapai Nowajganj	50
DPA Power	Pagla Army camp	50
Northern Power	Katakhali	50
TOTAL		**1,152**

Source: Energybangla, 30 September 2010

In spite of its rapid development the whole QRPP program (18 power plants) is unlikely to be completed in due time at the expected date of commissioning (April 2011). However, the program could presumably be on stream in the course of FY2012.

The Power Sector Development Program (PSDP)

PowerCell, the planning and research wing of the Power division of the Ministry, has been working for some time on the country's Power Sector Development Program (PSDP). This very ambitious project covers the FY2011-2015 period; it is part of the Power Sector Master Plan (PSMP), a long term planning exercise that encompasses the country's requirements up to 2030, and is set for being released in December 2010.

The version of the PSDP prepared in April 2010 considers four types of action, ranked by time priorities:

- *Immediate*: 6 -12 Months:

- Rental Plants (liquid fuels). This is the Quick Rental Programme

- *Short term*: 18 - 24 Months:
- Peaking Plants (liquid fuels)
- *Medium term*: 3 - 5 years:
- Combined Cycle Plants (Gas or dual fuel)
- Peaking Plant (Gas or dual fuel)
- Coal fired steam plants
- Renewable Energy
- *Long term*: beyond 5 years:
- LNG based Combined Cycle Plants
- Domestic/Imported Coal Power Plant
- Gas/Oil based Peaking Plant
- Nuclear Power Plant
- Renewable Energy

In total, the PSDP forecasts the construction of 9,426 MW between April 2010 and December 2015, based on domestic natural gas, coal, and oil products and renewables. The latter include 2,775 MW running on FO and 350 MW on diesel.

Table 2.17 - Schedule of Implementation of the Liquid Fuels-based Power Plants (PSDP)

	per calendar year	
Calendar year (CY)	HFO+Oil/Gas[19]	Diesel
2010 (April-December)	300	150
2011	620	0
2012	1,055	200
2013	500	0
2014	300	0
2015	0	0
cumulative	**2,775**	**350**

Source: PowerCell (PSDP, April 2010)

The PSDP is not fully consistent with the QRPP and the Peaking Plants programmes. In particular, the implementation schedule of the QRPP program (1,500 MW installed by FY2010-2011) is even more ambitious than the PSDP, which plans to have 1,070 MW installed by CY2011. However, we have considered that the PSDP plan, which forecasts an additional capacity of 3,125 MW in 5 years, would be met at the end of the period, even if the detailed year-wise schedule might not be met according to the plan. We have considered a 75-25 split between FO and diesel, which is consistent with the two-year QRPP program

[19] « Oil/Gas » plants are these plants scheduled to work on gas but which are designed to alternatively run on liquid fuels, should gas not be available.

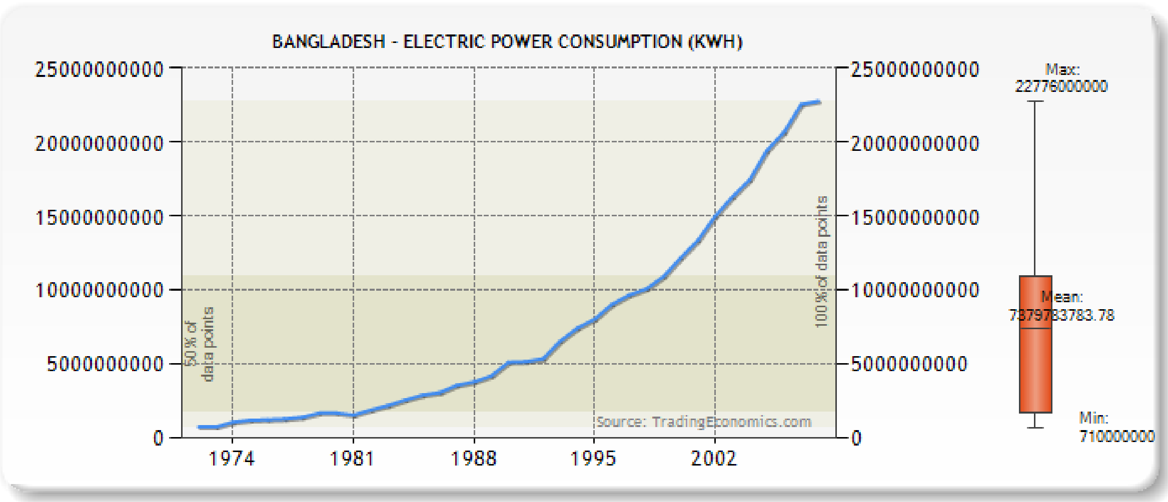
underway. The additional FO demand is expected to reach 2.15 million tons by 2015, and the additional diesel demand 0.69 million tons.

2.7.3. Long Term Projections (2016-2030)

Long term planning is taken care of by the Power Sector Master Plan, which is due by the end of the year. In the mean time we have assessed the long term oil requirements in the same way as for the other sectors, i.e. by reference to the growth of the GDP.

Between FY1996 and 2008 the electricity consumption has grown at an average rate of 8% p.a., i.e. 2.4 percentage points above the GDP rate. There again, it is a common phenomenon in developing economies that energy demand, in particular electricity, increases significantly faster than the overall economy, as industry and businesses develop and the population requires (when they can afford it) better comfort and living conditions. In Bangladesh, the impressive development of the rural electricity programme (over 8 million connections) carried by the Rural Electrification Board (REB) is substantially contributing to the growth of the electricity demand.

Figure 2.18 - Electricity Demand Growth



Source: Tradingeconomics

We have assumed that the short and medium term power programmes implemented over the first half of the present decade would about succeed in filling the gap between the actual, insufficient production level and the real, unconstrained demand. We have also considered that the implementation of new, more efficient power plants – whether on liquid fuels or gas – would significantly reduce the primary fuels requirements of the power facilities. As a result the mark up between the fuel consumption growth rate and the GDP growth rate has been downscaled from 2.4 to 2 percentage points over the FY2016-2020 period, and 1.5 point from FY2021 to 2030.

The FO consumption is expected to reach 3.4 million tons in 2020 and 6.9 million tons in 2030. The respective figures for diesel consumption are 1.3 and 2.6 million tons.

3. Matrices

The two tables hereunder summarize the value of the macro-economic indicators considered for the demand projections, by sectors and products, and for the three forecast periods (FY2011-2015; FY2016-2020); FY2021-2030).

Reference indicators. Certain growth rate values are connected to a sectoral GDP or to the overall (countrywide) GDP, others are related to other reference values, or have been applied a specific treatment. The bottom right figure shows the value of the overall GDP.

Table 2.19 – Reference Indicators

	Power	Industry	Agric	Road Transp.	Air Transp	Res & Com	Others	Overall GDP
Jet Fuel					Sectoral growth rate			
Premium				Sectoral growth rate				
Regular				Sectoral growth rate				
Kero						ad hoc calculation		
Diesel	Specific	Industry GDP	agriculture GDP	overall GDP		ad hoc calculation	road transp.	
Fuel oil	Specific	Industry GDP					road transp.	
Sectoral GDP	Overall +2.5%	overall +1.6%	Overall -1.8%	overall GDP				6.0%

Table 2.20 - Period Growth Rates:

FY2011-FY2015

	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	Overall
Jet Fuel					4.5%			
Premium				PBC proj.				
Regular				PBC proj.				
Kero						0.0%		
Diesel	PSDP	7.4%	4.2%	6.0%		0.0%	6.0%	
Fuel oil	PSDP	7.4%					6.0%	
sectoral GDP		overall +1.4%	Overall -1.8%	overall GDP				6.0%

FY2016-FY2020

	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	Overall
Jet Fuel					4.5%			
Premium				4.0%				
Regular				4.0%				
Kero						0.0%		
Diesel	8.0%	7.2%	4.0%	5.8%		0.0%	5.8%	
Fuel oil	8.0%	7.2%					5.8%	
sectoral GDP	Overall +2%	overall +1.2%	Overall -2%	Overall -0.2%				6.0%

FY2021-FY2030

	Power	Industry	Agric	Road Transp	Air Transp	Res & Com	Others	Overall
Jet Fuel					4.5%			
Premium				4.0%				
Regular				4.0%				
Kero						-1.0%	5.6%	
Diesel	7.5%	7.0%	3.8%	5.6%		-1.0%	5.6%	
Fuel oil	7.5%	7.0%						
sectoral GDP	Overall +1.5%	overall +1%	Overall -2.2%	Overall -0.4%				6.0%

4. Other Products

As mentioned above, the main six products account for 92% of the overall consumption of oil products. The other products are (in decreasing order): bitumen (3.9%), LPG (2%), lubricants (1.5%), jute batching oil (0.5%), and spirits (0.2%). None of these products may have any impact neither on the operation of the refinery nor on the capacity design of either the expansion of ERL or the construction of a new refinery. Indeed, except for jute batching oil, the BPC marketing companies sell in the market whatever the ERL produces, and the rest of the demand is met by the private sector that is now entitled to market bitumen, LPG and lubricants. The private sector has marketed in FY2009-10 close to 70% of these three products, and its share is steadily increasing (see Table below, in tons).

Products	BPC Sales	Private Sector Sales (estimate)	Total	Share of Private Sector
Bitumen	59,700	100,000	159,700	62.6%
LPG	16,600	65,000	81,600	79.7%
Lubricants	15,900	45,000	60,900	73.9%
Total	92,200	210,000	302,200	69.5%

The development of these three products is recent; we lack background data and historical series that would allow to make correlations between the past evolution of the demand and general indicators. We have tentatively considered a conservative 3% p.a. growth rate:

Products	FY2014-15	FY2019-20	FY2029-30
Bitumen	185,100	214,600	288,400
LPG	94,600	109,700	147,000
Lubricants	70,600	81,800	109,900
Total	350.300	406,100	545,300

5. Summary tables

Table 2.21 – Demand Projections (Main Six Products)

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

CHAPTER 3: LOCAL SALES AND STORAGE

The review of the depots focuses on the analysis of the regional sales and storage capacity. It is conducted on a regional basis.

The figures shown in the tables present the **net capacity** of the facilities, i.e. the gross capacity (overall volume available) minus the deadweight, as of May 2010, according to the figures and charts handed over by BPC and the oil companies. Figures include the capacity of those tanks that were under maintenance or repair at the time of the assessment mission. They include the capacity of the tanks that were under construction, as noted by the oil companies.

1. Chittagong area

The Chittagong area is only supplied by the main installations of the three oil companies.

1.1. Sales

The Chittagong region is the second largest sales area, only second to Dhaka. Local sales have reached 726,513 tons in FY2009-2010. All three companies have of course their own main installations that cater for both the local market and the dispatch to the other depots upnorth.

The MI are the only depots throughout the country that sell all the types of products, due their location next to the refinery. They are also the only depots that sell some specialty products with a limited market, such as SBP and MTT, and the bitumen produced by the refinery.

Chittagong accounts for 19.4% of all sales countrywide (18.2% of the main six products). The economic and industrial activity of the country's main harbour and second industrial area explains, to some extent, such a high share.

The fuel oil demand is extremely high, in spite of the fact that there is only one mid-size FO-based power plant in Shikolbaha. While we do not have the detailed breakdown of the sales, there are two possible explanations for such a high demand: (a) the sales include marine bunkers (around 75,000 tons), and (b) the sales to some large consumers (e.g. PDB) are accounted for in Chittagong, even when the actual consumption site is located elsewhere.

Table 3.1 - Local Sales at Chittagong (MI), FY2009-2010

	Sales (tons)	*Share in country's total sales (%)*
Premium gasoline	16,039	*18.8*
Regular gasoline	6,891	*5.4*
Kerosene	55,049	*14.6*
Diesel oil	380,125	*14.8*
Fuel oil	157,923	*81.3*
Jet Fuel	44,824	*15.6*
Main six products	**660,851**	**18.2**
Others	65,662	
Total	**726,513**	

1.2. Storage Capacity

The total capacity of the storage tanks is 304,000 tons for the three oil companies. The storage capacity of the main six products is 287,400 tons. It comes as a surprise that the size of the MI does vary significantly between the three companies, although their share in the overall sales at country level is fairly balanced – except jet fuel and some minor specialties that have been attributed to Padma at the creation of the three companies. Meghna accounts for about half the total capacity (46%), followed by Padma (29%) and Jamuna (25%)

Table 3.2 - Storage Capacity at Main Installations (net)

	metric tons				*percentage*		
	JAMUNA	MEGHNA	PADMA	**TOTAL**	*JAMUNA*	*MEGHNA*	*PADMA*
Premium gasoline	2,080	3;650	3,805	**9,155**	*22.7*	*35.7*	*41.6*
Regular gasoline	5,975	6,975	3,915	**19,395**	*30.8*	*49.0*	*20.2*
Kerosene	13,990	21,500	12,095	**55,085**	*35.4*	*52.6*	*22.0*
Diesel oil	35,985	45,150	33,325	**150,485**	*23.9*	*53.9*	*22.8*
Fuel oil	13,800	17,700	5,120	**35,080**	*39.3*	*46.1*	*14.6*
Jet Fuel			24,220	**24,220**			*100.0*
Main six products	***71,830***	***94,975***	***82,480***	***293,420***	***24.5***	***47.4***	***28.1***
Others	3,905	2,500	5,585	**10,840**	*36.0*	*12.4*	*51.5*
Total	**75,735**	**97,475**	**88,065**	**304,260**	***24.9***	***46.2***	***28.9***

1.3. KPCL

The Khulna Power Company Limited (KPCL) operates a mid-size FO-run power plant (105 MW) at Daulatpur near Khulna. They have received from BPC a derogation to procure their fuel from outside the BPC group, due to the inability of BPC to supply the required quantities. Their requirements are estimated at 91,600 tons per year[20]. KPCL import fuel oil from Singapore in cargoes of up to 17,000 tons and store it in 2 tanks with a total capacity of 18,000 tons at the terminal named "South Eastern Tank Terminal Ltd" at North Patenga, near the Meghna / Jamuna main installations. The terminal has some more tanks, with a total capacity of 115,000 tons, (including the 2 FO tanks rented by KPCL). The other tanks are being used for different non-energy operators, mostly for edible oil. Currently import is made on one cargo per month, and they can receive more (or larger) cargoes if required.

2. Barisal area

The Barisal Division is one of the two smallest Divisions (with Sylhet) in Bangladesh. It is supplied through six small size depots located in two sites: Barisal (the regional capital), and Jhalakati. All three companies have their depot each in both Barisal and Jhalakati, although the distance between the two sites is moderate. Both depots are supplied by coastal tankers out of Chittagong.

2.1. Sales

Regional sales are limited to the basic three products: regular gasoline (MS), diesel oil (HSD) and kerosene (SKO). There is no premium gasoline nor fuel oil sold there. Sales have reached 183,000 tons in FY2009-2010, i.e. 5% of the country's total sales, less than its demographic share (6.5%). Diesel oil represents the bulk of the sales (79%) followed by kerosene (16%) and regular gasoline (5%).

While all three companies store and sell both kerosene and diesel oil at both depots, the sale of regular gasoline has been distributed between the companies: Jamuna at Barisal, Meghna and Padma at Jhalakati.

Table 3.3 - Local Sales in the Barisal Area, FY2009-2010

	Barisal (tons)	Jhalakati (tons)	Total (tons)	*Share in country's total sales (%)*
Regular gasoline	3,284	6,033	9,317	*7.3*
Kerosene	16,143	13,109	29,252	*7.8*
Diesel oil	82,012	62,652	144,664	*5.6*
Main six products	**101,439**	**81,794**	**183,233**	**5.0**

[20] For half-base operation (4,380 hours per year) and 40% efficiency.

2.2. Storage Capacity

The Barisal depot is a conventional land depot, while the Jhalakati depot consists of several barges. Each barge is dedicated to one given product (e.g. Jamuna has one barge for kerosene and one for diesel). Both are small size depots, with an overall net capacity of 6,600 tons in Barisal and 3,200 tons in Jhalakati.

Each of the three companies operates a depot in both Barisal and Jhalakati. All store kerosene and diesel oil, but only Jamuna operates a MS storage in Barisal, while Meghna and Padma operate their own MS storage barges in Jhalakati.

With 50% of the storage capacity in Barisal and 42% in Jhalakati, Meghna is the principal operator in the South, followed by Jamuna and Padma.

Table 3.4 - Storage Capacity at Barisal (net)

	metric tons			
	JAMUNA	MEGHNA	PADMA	**TOTAL**
Regular gasoline	145	--	--	**145**
Kerosene	455	1,120	320	**1,895**
Diesel oil	2,035	2,150	340	**4,525**
Main six products	**2,635**	**3,270**	**660**	**6,565**
Share of each Company (%)	*40.1*	*49.8*	*10.1*	

Table 3.5 - Storage Capacity at Jhalakati (net)

	metric tons			
	JAMUNA	MEGHNA	PADMA	**TOTAL**
Kerosene	300	250	455	**1,005**
Diesel oil	310	820	665	**1,795**
Main six products	**610**	**1,320**	**1,250**	**3,180**
Share of each Company (%)	*19.2*	*41.5*	*39.3*	

3. Daulatpur (Khulna)

The storage facilities of Daulatpur, in the northern suburbs of Khulna, are one of the key infrastructure of the BPC group on several counts:

- It supplies the third most populated city of the country, with over 1 million people

- It is the only depot in the whole Khulna Division, and in the area south of the Padma-Meghna river system[21]. As such, it does not only serves the consumers of the Division but also those of the five districts on the southern bank of the Padma-Meghna that belong to the (administrative) Dhaka Division, but are not connected by a fixed link to the rest of the Division[22]. The coverage area of the depot, which corresponds to the oil marketing 'Region' is well over 20 million people.
- There are three power stations located in the area. While KPCL are directly supplied from their own storage facility in Chittagong (see para. 3.1 above), the other two are supplied from Daulatpur.
- It is one of the four depots[23] that play the role of both a regional facility serving their local customers, and a transfer point for other depots upnorth.

3.1. Sales

Due to the size of the area covered by the depots the volumes of local sales are important, of the same order of magnitude as Chittagong's MI and Godnail. All the main six products are marketed, including a small volume of jet fuel intended for the Air Force at Jessore Airport (civil aircraft do not refuel at Jessore). Diesel oil accounts for an overwhelming 83% of the total 489,000 tons sold. Fuel oil is intended for the KPS and KPCL power plants nearby.

Table 3.6 - Local Sales Daulatpur, FY2009-2010

	Sales (tons)	*Share of products (%)*	*Share in country's total sales (%)*
Premium gasoline	8,181	*1.4*	*9.6*
Regular gasoline	26,958	*4.6*	*21.1*
Kerosene	41,768	*7.1*	*11.1*
Diesel oil	488,873	*83.3*	*19.0*
Fuel oil	19,923	*3.4*	*10.3*
Jet Fuel	863	*0.1*	*3.0*
Main six products	**586,566**	**100.0**	**16.1**
Others	11,882		
Total	**598,448**		

3.2. Transfers

Over one-third of the 880,000 tons received at Daulatpur from Chittagong are forwarded to other depots located in the Northwest Division, and to power plants operated in both the

[21] Except Barisal and Jhalakati that have a limited capture area.
[22] At least, as long as the bridge planned across the Padma is not in operation.
[23] With Chittagong, Godnail and Fatullah.

Khulna and Northwest Divisions. Transfers only concern kerosene and diesel oil, and they are all made by railway, using the north-south broad gauge (BG) track.

The largest transfer is intended for the Parbotipur depots, located in the north of the Rajshahi Division. It concerns all the kerosene and most of the diesel oil sold in Parbotipur. All regular gasoline, however, is directly sent from Chittagong by rail, along with limited volumes of diesel (1,500 tons in FY2009-2010).

The other important route supplies the three railhead depots of Rajshahi, Natore and Harian, located in the west of the Rajshahi division.

The Bheramara power plant, located in the north of the Khulna Division, is supplied in diesel by rail from Daulatpur.

Table 3.7 - Transfers by Rail from Daulatpur, FY2009-2010

	To Parbotipur	To Rajshahi	To Natore	To Harian	TOTAL
Kerosene	24,374	3,730	4,264	936	33,304
Diesel oil	167,970	31,890	47,039	12,522	259,421
Total	**192,344**	**35,620**	**51,303**	**13,468**	**292,725**

3.3. Storage capacity

All three oil companies operate their own depot at Daulatpur. They are located side by side on the south bank of the river, between two bends of a rectilinear stretch the river. Each depot has its own jetty for unloading the incoming coastal tankers from Chittagong. Each depot also has a broad gauge railway siding to send out tank wagons to the north.

Figure 3.8 - Situation Map of the Storage Facilities at Daulatpur

Source: GoogleEarth

The picture above shows the location of the three depots; from west to east: Meghna, Jamuna and Padma. Railway sidings may be seen at the bottom of the picture. More to the east are the three power plants (KPCL, KPS and the Aggreko Quick Rental).

The total storage capacity is slightly above 30,000 tons, with only small variations between the three companies. All main six products can be stored, with diesel accounting for 59% of the overall capacity. Padma operates a small jet fuel tank of 2,900 tons. In addition, each company operates a small jute batching oil tank (JBO) and tanks and storage shelters for LPG, lubricants and packed products.

Table 3.9 - Storage Capacity at Daulatpur (net)

	metric tons			
	JAMUNA	MEGHNA	PADMA	**TOTAL**
Premium gasoline	330	325	365	**1,020**
Regular gasoline	685	620	1,035	**2,340**
Kerosene	1,845	975	1,760	**4,580**
Diesel oil	4,065	8,205	5,115	**17,385**
Fuel oil	1,135	1,100	1,510	**3,745**
Jet Fuel			415	**415**
Main six products	**8,060**	**11,225**	**10,200**	**29,485**
Others	395	370	390	**1,155**
Total	**8,455**	**11,595**	**10,590**	**30,640**
Share of each Company (%)	*27.6*	*37.8*	*34.6*	

3.4. Reception and storage at Power Plants

PDB's Khulna Power Station (KPS) is supplied by coastal tankers from Chittagong, which are directly unloaded at their own facilities. Cargoes consist of fuel oil and diesel oil, the latter intended for the Quick Rental Plant installed within their premises. There are three FO tanks, each with a capacity of 18 million liters (about 17,000 tons), and a smaller diesel tank of 2.1 million liters (about 1,700 tons). It may happen that the oil companies have to store additional volumes when the KPS tanks have not enough room left.

KPCL also have their own unloading facilities, and two FO tanks of 7,500 tons each.

Bheramara Power Station (BPS) receive diesel sent from Daulatpur by rail. They have their own railway siding and 3 diesel tanks with total capacity of about 20,000 m^3 (17,000 tons).

4. The Western Group (Rajshahi, Natore, Harian)

These are railhead transfer 'depots', i.e. the products are directly transferred upon arrival from the tank wagons into road tankers. There is no permanent storage, except a small 1,000-ton facility in Natore operated by Padma, and each facility has a shelter for storing lubricants and other packed products. The only liquid fuels received consist of kerosene and diesel oil that are sent from Daulatpur; there is no gasoline nor fuel oil sold.

4.1. Sales

The three depots handle 91,000 tons of diesel and 9,000 tons of kerosene. A substantial part of the diesel is sold during the dry season to actuate irrigation pumps.

All three oil companies are present in the Western Group, but not at each depot. Each company operates out of two sites: Jamuna and Padma at Natore and Rajshahi, Meghna at Natore and Harian. The largest activity takes place at Natore, where all companies are present, and the smallest at Harian, with only Megna present there.

Table 3.10 - Local Sales in the Western Group, FY2009-2010

	Natore (tons)	Harian (tons)	Rajshahi (tons)	Total (tons)	*Share in country's total sales (%)*
Kerosene	4,262	892	3793	8947	*2.3*
Diesel oil	47,430	12,435	33,144	93,009	*3.5*
Main six products	**51,692**	**13,327**	**36,937**	**101,956**	***2.8***
Share in country's total sales (%)	*1.4*	*0.4*	*1.0*	***2.8***	

4.2. Storage Capacity

Padma operates a small depot at Natore: 80 tons of kerosene and 870 tons of diesel oil, i.e. 950 tons in total.

5. The Northern Group (Parbotipur, Rangpur, Jamuna Barges)

The northern depots are located in the north of the Rajshahi Division. They play a key role for the agricultural sector as they contribute to the supply of diesel oil for irrigation pumps during the Rabi season in an area characterised by a high level of irrigated lands.

Parbotipur is a large-size depot located at an important railway crossroads, on the broad gauge track, 420 km to the north of Khulna. Rangpur is a small size facility, located in the largest city in the area, 50 km to the east of Parbotipur. They are supplied only by rail. The other two depots (Balashi and Chilmari) comprise of small size barges docked at the right bank of the Jamuna river.

5.1. Sales

Parbotipur is the second largest sales center in the Rajshahi Division; it ranks #6 in the list of regional sales, next to Baghabari. Sales have slightly exceeded 200,000 tons in FY2009-2010, comprising of mainly diesel oil (83%), along with kerosene (12%) and regular gasoline (5%). Small volumes of premium gasoline are shipped by lorry from the Baghabari depot. There is no fuel oil sold in the entire Division.

The Rangpur depot has a limited activity, with less than 20,000 tons of kerosene and diesel oil.

The Balashi and Chilmari barges help meeting the additional diesel oil demand in the winter time. These are small units, will low storage capacity and low output. The Chilmari barge has recorded minor sales of 4,000 tons of diesel in FY2009-2010. It is unclear whether the Balashi barge is still in operation. Sources in the industry mention that the barge has been returned by Jamuna to the owner; the Jamuna website still mentions it in the list of their operating facilities[24], but do not record any sales out of Balashi in FY2009-2010.

Table 3.11 - Local Sales in the Northern Area, FY2009-2010

	Parbotipur	Rangpur	Chilmari	Balashi	**TOTAL**	*Share in country's total sales (%)*
Regular gasoline	10,239	--	--	--	**10,239**	*8.0*
Kerosene	24,374	2,268	--	--	**26,642**	*7.1*
Diesel oil	169,446	17,069	3,904	n/a	**190,419**	*7.5*
Main six products	**204,059**	**19,337**	**3,904**	**n/a**	**227,300**	***6.2***
Share in country's total sales (%)	*5.6*	*0.5*	*0.1*	*n/a*	***6.2***	

5.2. Storage Capacity

All three oil companies operate their own depot at Parbotipur. The total storage capacity is 10,000 tons, of which 87% is dedicated to diesel. Kerosene and diesel are received from Daulatpur through the broad gauge railway line that originates in Khulna. Regular gasoline is supplied directly from the main installations at Chittagong by meter gauge tank wagons, which can travel seamlessly across the Jamuna bridge since the installation of a third rail has made the BG line a dual gauge track.

The three companies also operate each a depot at Rangpur, a much smaller facility, with 3,200 tons of total capacity. Storage capacity is about balanced between kerosene and diesel, complemented by two small tanks for regular and premium gasoline. All products are transported all the way by meter gauge trains from Chittagong, as the Parbotipur-Rangpur line has not been adjusted yet for dual gauge.

[24] Dated 16 June 2010.

Jamuna and Meghna operate barges anchored at Chilmari on the Jamuna. The former stores kerosene and diesel, while the latter stores only diesel. The overall capacity reaches 850 tons.

Table 3.12 - Storage Capacity in the Northern Area, FY2009-2010

	Parbotipur	Rangpur	Chilmari	Balashi	**TOTAL**[25]	*Share of each company(%)*
JAMUNA						
Regular gasoline	105	--	--	--	**105**	
Kerosene	305	325	195	(110)	**825**	
Diesel oil	2810	230	390	(110)	**3430**	
Sub-total	**3220**	**555**	**585**	**(220)**	**4360**	*30.9*
MEGHNA						
Regular gasoline	100	--	--	--	**100**	
Kerosene	300	565	--	--	**865**	
Diesel oil	2820	1125	370	--	**4315**	
Sub-total	**3220**	**1690**	**370**	**--**	**5280**	37.4
PADMA						
Premium gasoline	--	35	--	--	**35**	
Regular gasoline	110	30	--	--	**140**	
Kerosene	330	475	--	--	**805**	--
Diesel oil	3080	420	--	--	**3500**	
Sub-total	**3520**	**960**	**--**	**--**	**4480**	*31.7*
ALL 3						
Premium gasoline	--	35	--	--	**35**	
Regular gasoline	315	30	--	--	**345**	
Kerosene	935	1365	195	--	**2495**	
Diesel oil	8710	1775	760	--	**11245**	
Main six products	**9960**	**3205**	**955**	**(220)**	**14120**	

[25] Does not include Balashi

6. Baghabari

The Baghabari depot is the largest in the Rajshahi Division. It is located in the south-eastern corner of the Division, on a right tributary of the Jamuna. All products are received by water using shallow draft tankers (SDT). Incoming SDTs are loaded in the two depots of the Dhaka area, Godenail and Fatullah. Some SDTs have been certified for sea journey across the Bay of Bengal and can travel directly from Chittagong when weather allows it.

6.1. Sales

Total sales have reached 317,000 tons in FY2009-2010, broken down into diesel (79%), regular gasoline (11%), kerosene (9%), and premium (1%). There is no sales of jet fuel and fuel oil. Additional products include LPG and lubricants.

Table 3.13 - Local Sales Baghabari, FY2009-2010

	Sales (tons)	*Share of products (%)*	*Share in country's total sales (%)*
Premium gasoline	4,634	*1.5*	*5.4*
Regular gasoline	33,719	*10.6*	*26.5*
Kerosene	29,490	*9.3*	*7.8*
Diesel oil	249,219	*78.6*	*9.7*
Main six products	**317,062**	***100.0***	***8.7***
Others	2,570		
Total	**319,632**		

6.2. Storage Capacity

The size of the depots is commensurate with the high level of sales. With close to 40,000 tons, Baghabari is the largest depot outside Chittagong's main installations. The three companies operate their own facilities, which are about the same size. They store and market the same types of products.

Table 3.14 - Storage Capacity at Baghabari (net)

	metric tons			
	JAMUNA	MEGHNA	PADMA	**TOTAL**
Premium gasoline	165	165	130	**460**
Regular gasoline	385	430	985	**1,800**
Kerosene	1,415	1,040	1,655	**4,110**
Diesel oil	11,560	10,860	10,625	**33,045**
Main six products	**13,525**	**12,495**	**13,395**	**39,415**
Share of each Company (%)	*34.3*	*31.7*	*34.0*	

7. Dhaka area (Godenail, Fatullah)

The two storage sites are installed in Narayanganj, an industrial and port area located to the southeast of Dhaka. They are easily accessible by water from Chittagong, and can 're-export' cargoes to other sites downstream (Chandpur) or upstream the Meghna river system (Ashuganj, Bhairab, Sachna Bazar) and the Jamuna system (Baghabari and Chilmari). There are no railway sidings.

Not all three oil companies are installed in both sites. Jamuna only operates out of Fatullah, and Padma only out of Godenail. Meghna is installed at both Godenail and Fatullah, although their Fatullah depot is a small-size facility set on a small plot of land with no extension possible. Fatullah is only a local sales center, and all transfer activities are conducted by Meghna in Godenail

7.1. Sales

Combined sales in the Dhaka area reached 1.1 million tons in FY2009-2010; they accounted for 29% of the country's consumption, including 18% for Godenail and 11% for Fatullah.

As usual, diesel oil accounts for the higher share (60%) but this share is not as high as in most other depots, due to the presence of jet fuel (22%) and premium and regular gasoline (7%).

Table 3.15 - Local Sales at Godenail and Fatullah, FY2009-2010

	Godenail (tons)	Fatullah (tons)	TOTAL tons)
Premium gasoline	28,294	17,969	46,263
Regular gasoline	15,428	9,210	24,638
Kerosene	30,349	58,898	89,247
Diesel oil	327,856	323,181	651,037
Fuel oil	13,528	2,791	16,319
Jet Fuel	241,251	--	241,251
Main six products	**656,706**	**412,049**	**1,068,755**
Others	8,503	5,581	14,084
Total	**665,209**	**417,630**	**1,082,839**

7.2. Transfers

Godenail and Fatullah are important transfer points to Baghabari and Chilmari in the Northwest, and Sachna Bazar in the northeast. Additional cargoes are directed to Ashuganj, Bhairab, Chandpur and Sylhet when required.

The largest transfer destination is the Baghabari depot, a pivotal site for the delivery of diesel oil to the Rajshahi Division during the dry season. Baghabari receives 85% of its 320,000 tons from Godenail and Fatullah in SDTs, while the balance travels directly from the MI in seagoing certified SDTs.

The volumes sent to Sachna Bazar (10,000 tons) and Chilmari (4,000 tons), also by SDTs, are much smaller.

7.3. Ships Movements

Godenail is the largest oil harbour – except Chittagong, of course – in terms of volumes handled and number of ships movements. About 770 coastal tankers have been received from the MI in FY2009-2010, carrying 880,000 tons of products (both local sales and transfers), i.e. 1,150 tons/movement in average.

Table 3.16 – Coastal Tankers Movements at Godenail, FY2009-2010

	MEGHNA[26]	PADMA	**TOTAL**
Coastal Tankers received	208	561	**769**
Weekly average	4	11	**15**

Meghna transfers products only to Baghabari, with 3 to 4 SDTs per week in summer and 8 to 10 in winter. Padma operates at about the same frequency to Baghabari, and supplies also cargoes to Ashuganj as well to the Gorasal power plant nearby, in addition to the volumes receives directly from the MI.

The activity at Fatullah is about two-thirds of Godenail. Jamuna receives in average one daily coastal tanker during the rainy season, and two daily ships in winter. Transfers to depots upstream include three SDTs per week in summer and one daily in winter. Meghna receives 12 coastal tankers per month in average, all for local sales; there is no trans-shipment.

7.4. Storage Capacity

The combined storage capacity of the two sites is 31,000 tons. Godenail is larger (17,000 tons) than Fatullah (14,000 tons) in part due to Padma's jet fuel storage in Godenail.

Table 3.17 - Storage Capacity at Godenail (net)

	MEGHNA	PADMA	**TOTAL**
Premium gasoline	560	650	**1,210**
Regular gasoline		670	**670**
Kerosene	1,160	1,100	**2,260**
Diesel oil	4,240	3,290	**7,530**
Fuel oil	1,460	560	**2,020**
Jet fuel		2,900	**2,900**
Main six products	**7,420**	**9,190**	**16,610**
Share of each Company (%)	*45*	*55*	

[26] Estimate based on the first ten months.

Table 3.18 - Storage Capacity at Fatullah (net)

	JAMUNA	MEGHNA	**TOTAL**
Premium gasoline	1,330	620	**1,950**
Regular gasoline	1,235	430	**1,665**
Kerosene	1,205	850	**2,055**
Diesel oil	5,125	2,460	**7,585**
Fuel oil	1,075		**1,075**
Main six products	**9,970**	**4,360**	**14,330**
Share of each Company (%)	*70*	*30*	

8. The East and Northeast

The East and Northeast regions display a particular structure of storage sites. There are no less than 8 locations, from Chandpur through Sylhet.

8.1. Sales

All sites have sold 460,000 tons of the main six products in FY2009-2010, which accounts for less than 13% of the total sales at country level.

The sales are almost evenly distributed into three geographical sub-areas centered on Chandpur, Bhairab and Sylhet.

Table 3.19 - Local Sales in the Northeast and East, FY2009-2010

	Chandpur	Ashuganj Bhairab Brahman Baria	Sylhet Srimongal Sachna Bazar Mogla Bazar	TOTAL
Premium gasoline	877	--	2,993	3,870
Regular gasoline	2,645	2,915	1,116	6,676
Kerosene	47,367	24,214	24,686	96,267
Diesel oil	94,288	146,452	113,763	354,503
Main six products	**145,177**	**173,581**	**142,558**	**461,516**

8.2. Storage Capacity

With but the exception of Chandpur, the cumulative capacity of the oil companies in each site do not exceed 4,000 tons.

Table 3.20 – Storage Capacity in the Northeast and East

	Chandpur	Ashuganj Bhairab Brahman Baria	Sylhet Srimongal Sachna Bazar Mogla Bazar	TOTAL
Premium gasoline	30	---	695	725
Regular gasoline	590	30	1,335	1,955
Kerosene	3,270	2,140	2,890	8,300
Diesel oil	5,000	3,680	3,840	12,520
Main six products	**8,890**	**5,850**	**8,160**	**23,500**

CHAPTER 4: SECURITY OF SUPPLY

1. STORAGE CAPACITY

1.1. Products Flows

To assess the suitability of the storage facilities for the volumes of oil products that are stored in the depots, one must consider the overall quantities of products passing through the storage tanks.

Due to the route structure of the distribution of the oil products in Bangladesh, the depots handle two types of products, depending on their destination:

- The products intended to be sold in the local market, and
- The products that pass through the depot prior to being forwarded to their final destination.

For the former products, the depot constitutes their final destination before being loaded into a local distribution vehicle (tanker lorry). Conversely, the latter include the transshipment or transfer depots, where products are received from an upstream origin, stored, and loaded again onto a different means of transport towards their final destination. These transfer depots play a role similar to an airport hub in commercial aviation.

There are four such hubs in Bangladesh:

- The main installations (MI) in Chittagong,
- Godenail and Fatullah in the greater Dhaka area, and
- Daulatpur (Khulna).

The **MI** handle the totality of the oil products marketed by the oil companies, whether produced by the ERL or imported. The volumes of products handled amounted to over 3.6 million tons in FY2009-2010, when only the main six products are considered.

Godenail and **Fatullah** receive all the products they handle from the MI by coastal tanker. A substantial part of the cargoes received are routinely transferred onto shallow draft tankers (SDT) and forwarded to the Northwest over the Jamuna river (Baghabari, Chilmari and Balashi) and the Northeast over the Meghna and tributaries (Sachna Bazar). In addition to these destinations, some depots that are not supplied through Godenail or Fatullah on a regular basis may receive some spot cargoes from these depots, e.g. to meet additional demand. As an example, Sylhet, a depot normally supplied by meter gauge rail from the MI, has received in FY2009-2010 2,200 m^3 of kerosene and diesel sent by SDT from the Jamuna depot in Fatullah, which had not been required in FY2008 and 2009.

Daulatpur is an important hub for the Northwest, i.e. the Rajshahi Division. The depots receive all oil products from the MI in coastal tankers. Part of them are forwarded upnorth by rail (broad gauge) to four railhead depots: Parbotipur, Rajshahi, Natore and Harian, as well as to power plants located along the railway line and equipped with a railway siding[27].

Conversely, the diesel and fuel oil consumed by the three power pants located on the river[28] near the Daulatpur depots are usually directly handled by their own unloading and storage facilities, without physically passing through the depots of the oil companies.

Table 4.1 - Total Oil Products Flows[29] at Transfer Depots (thousand tons)

Transfer Depots	Transfer Operators	Volumes Transferred	Local sales	**Total Flows**	*Share of Volumes Transferred (%)*
Chittagong - MI	All	2,978	661	**3,639**	*81.8*
Godenail	Meghna, Padma	224	657	**881**	*25.4*
Fatullah	Jamuna	105	412	**517**	*20.3*
Daulatpur	All	304	587	**891**	*34.1*
Other depots (non hub)		--	1,322	**1,322**	
TOTAL		3,611	3,639	**7,250**	*49.8*

Table 4.1 above shows that the depots handle in total over 7.2 million tons, i.e. twice as much as is required to supply their local market. Table 4.2 overleaf gives the detailed flows data for FY2009-2010.

[27] Bheramara PS, Sayedpur PS.
[28] Khulna PS, Khulna Quick Rental, KPCL.
[29] Main six products (Premium and regular gasoline, kerosene, diesel oil, fuel oil, jet fuel). Excluding the volumes from gas fields

Table 4.2 - Oil Products Flows, FY2009-2010

		HOBC	MS	SKO	HSD	FO	JET	TOTAL
Southeast	**CHITTAGONG - MI**	85,535	127,247	376,655	2,568,158	194,165	286,938	**3,638,698**
Dhaka	**GODENAIL**	32,180	42,724	48,436	503,096	13,528	241,251	**881,215**
and Central	**FATULLAH**	18,717	15,633	71,098	408,352	2,791		**516,591**
	EPOL Dhaka	6,554	2,149		17,867			**26,570**
	Chandpur	877	2,645	47,367	94,288			**145,177**
	Ashuganj			10,545	37,070			**47,615**
	Bairab			13,669	106,101			**119,770**
Northeast	Sylhet	1,159	4,838	15,564	56,374			**77,935**
	Mogla Bazar			24	4,411			**4,435**
	Sachna Bazar			797	9,805			**10,602**
	Sreemongal	1,828	2,938	8,311	43,173			**56,250**
	Brahman Baria		2,915		3,281			**6,196**
Northwest	Baghabari	4,634	33,719	29,490	249,219			**317,062**
	Parbatipur		10,239	24,374	169,446			**204,059**
	Rangpur			2,268	17,069			**19,337**
	Balashi							
	Chilmari				3,904			**3,904**
	Natore			4,264	47,039			**51,303**
	Harian			936	12,522			**13,458**
	Rajshahi			3,730	31,890			**35,620**
Southwest	**DAULATPUR**	8,181	37,197	75,072	749,770	19,923	863	**891,006**
	Barisal		3,284	16,143	82,012			**101,439**
	Jhalakati		6,033	13,109	62,652			**81,794**
TOTAL		**159,665**	**291,561**	**761,852**	**5,277,499**	**230,407**	**529,052**	**7,250,036**

Note: Transfer depots are mentioned in bold CAPITAL letters

1.2. Capacity / Flow Ratio

The ratio is meant to assess the ability of a depot to (a) operate efficiently under normal operation, and (b) response to a supply risk or stress situation, such as a temporary interruption of supply or an unexpected surge in demand.

The assessment has been conducted for each depot and each product, based on the flows passing through the depot, and the net storage capacity of the depot.

The indicator is the number of average days of storage (ADS), i.e. the number of days that it takes to empty a full reservoir. It is measured by the ratio of the net capacity storage to the *average* daily flow[30] (yearly flow divided by 365).

Below a certain number of ADS, it is considered that the operation of the depot (at least for one product) is at risk, i.e. the depot is not able to face an emergency situation and shortage is very likely to occur.

There is no fixed rule to determine the desirable minimum number of ADS. It depends to a large extent on the local conditions, in particular the delay required to organize, transport and receive additional cargoes in case of technical problem at the depot, or to find and operate an alternative supply route in case of supply disruption. Following discussions with depot operators, we consider that, in order to ensure a sound and efficient operation of the depot, the tanks should keep a minimum stored volume equivalent to two weeks (14 days) of average sales. Below one week (7 days and below) there is a very serious risk of shortage, even if the risk-causing situation does not last for very long[31].

At **country level**, the capacity / flow ratio is generally satisfactory for most products. The number of ASD is 20, with moderate variations between the oil companies (from 17 to 24), which reflects the somewhat similar size of both their respective market shares and the overall storage capacity of their depots. Meghna shows the best performance, followed by Jamuna and Padma

The results are even better with regard to the **main installations**. The overall number of ASD is 25, with variations from 23 to 30.

The analysis shows that there is a serious shortage risk for two products (**diesel** and **jet fuel**) and in the three transfer depots of **Godenail** and **Fatullah**, and **Daulatpur**. Two small depots show strong risks: Bhairab (for diesel oil) and Brahman Baria (for regular gasoline).

Table 4.3 – Major Shortage Risks (Storage Sites and Products) in Average Operation

	Number of Average Storage Days (ASD)			
	Diesel Oil			Jet A-1
	Jamuna	Meghna	Padma	Padma
Godnail		7	4	4
Fatullah	7	7		
KAD				4
Daulatpur	6	12	7	

[30] i.e. the yearly flow divided by 365.
[31] Such as the shortage of jet fuel caused by the strike of the marine workers in May 2010.

Table 4.4 – Number of Average Days of Storage (All Oil Companies)

		HOBC	MS	SKO	HSD	FO	JET	Average
Southeast	**CHITTAGONG-MI**	41	48	46	16	69	31	25
Dhaka	**GODNAIL**	14	9	17	5	55	4	7
	FATULLAH	30	39	11	7	141		10
	EPOL Dhaka	31	53		53			48
	Chandpur	12	82	25	19			22
	Ashuganj			26	18			20
	Bairab			37	6			9
Northeast	Sylhet	26	34	34	12			18
	Mogla Bazar			4,258	23			90
	Sachna Bazar			89	8			14
	Sreemongal	79	72	43	13			23
	Brahman Baria		4		18			11
Northwest	Baghabari	36	19	51	48			45
	Parbatipur		11	14	19			18
	Rangpur			220	38			61
	Balashi							
	Chilmari				62			80
	Natore			11	7			7
	Harian			0	0			0
	Rajshahi			0	0			0
Southwest	**DAULATPUR**	46	23	22	8	69	176	12
	Barisal		16	43	20			24
	Jhalakati		23	28	10			14
Country		34	34	36	15	69	19	20

Table 4.5 – Number of Average Days of Storage (Jamuna)

		HOBC	MS	SKO	HSD	FO	JET	Average
Southeast	CHITTAGONG-MI	33	57	39	16	45		23
Dhaka	GODNAIL							
	FATULLAH	24	36	12	7	141		10
	EPOL Dhaka							
	Chandpur		82	37	17			27
	Ashuganj							
	Bairab			30	4			7
Northeast	Sylhet	33	45	33	14			21
	Mogla Bazar							
	Sachna Bazar			89	8			14
	Sreemongal	660	210	72	24			47
	Brahman Baria							
Northwest	Baghabari	80	22	45	56			53
	Parbatipur		11	14	19			18
	Rangpur			134	16			32
	Balashi							
	Chilmari				57			85
	Natore							0
	Harian							
	Rajshahi							0
Southwest	DAULATPUR	40	19	28	6	52		10
	Barisal		16	27	20			20
	Jhalakati			33	12			17
Country		34	42	33	14	47		20

Table 4.6 – Number of Average Days of Storage (Meghna)

		HOBC	MS	SKO	HSD	FO	JET	Average
Southeast	**CHITTAGONG-MI**	43	67	54	18	178		30
Dhaka	**GODNAIL**	19	11	15	7	81		10
	Fatullah	47	53	9	7			9
	EPOL Dhaka	33	54		63			54
	Chandpur			22	31			28
	Ashuganj							
	Bairab			39	5			8
Northeast	Sylhet							
	Mogla Bazar			4,258	23			90
	Sachna Bazar							
	Sreemongal	24	64	39	10			17
	Brahman Baria							
Northwest	Baghabari	34	17	43	45			42
	Parbatipur		16	14	19			18
	Rangpur			236	70			92
	Balashi							
	Chilmari				71			71
	Natore							
	Harian							
	Rajshahi							
Southwest	**DAULATPUR**	49	21	14	12	67		14
	Barisal			90	25			34
	Jhalakati		29	18	14			17
Country		39	43	38	17	151		24

Table 4.7 – Number of Average Days of Storage (Padma)

		HOBC	MS	SKO	HSD	FO	JET	Average
Southeast	CHITTAGONG-MI	44	28	43	15	42	31	22
Dhaka	GODNAIL	11	9	20	4	31	4	6
	FATULLAH							
	EPOL Dhaka							
	Chandpur	12		18	8			11
	Ashuganj			26	18			20
	Bairab			94	27			35
Northeast	Sylhet	21	20	37	9			14
	Mogla Bazar							
	Sachna Bazar							
	Sreemongal	15	36	10	10			11
	Brahman Baria		9		33			23
Northwest	Baghabari	23	20	66	45			42
	Parbatipur		9	14	19			18
	Rangpur			343	26			55
	Balashi							
	Chilmari							
	Natore			20	16			16
	Harian							
	Rajshahi							
Southwest	DAULATPUR	49	28	25	7	93	176	12
	Barisal			23	9			13
	Jhalakati		16	34	8			11
TOTAL BD		31	21	35	13	46	19	17

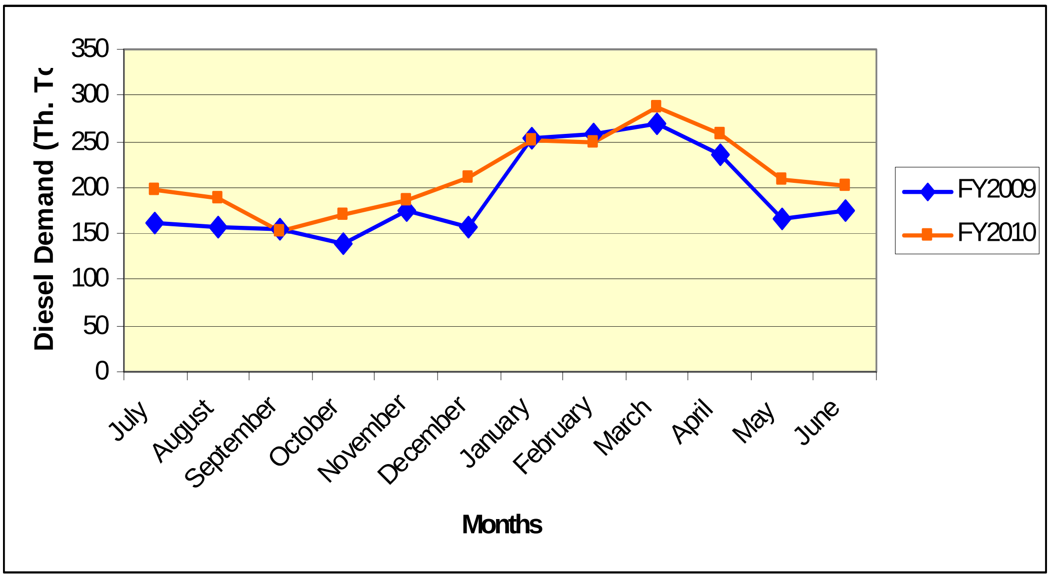
1.3. Diesel oil

With regard to oil products, the most worrying situation is that of diesel oil. In average, i.e. outside the dry season, four depots show an ASD equal to or lower than 7 days; 5 depots an ASD ranging from 8 to 13 days; and 10 are beyond 14 days (Tables 4.4 to 4.7 above show the number of average days of storage, for each depot and oil product, and for each company).

The situation becomes worse during the dry season (December to April). The diesel demand increases dramatically, in particular in the northwest (Rajshahi Division) where irrigation pumps require large quantities of energy in the form of diesel and electricity.

Figure 4.8 shows that the additional demand concerns the whole country. During FY2008-2009 and FY2009-2010 core Rabi season (January-April) the average monthly demand was respectively 33% and 22% higher than the yearly average, and 59% and 39% higher than the low season average (the 8 off-peak months).

Figure 4.8 - Monthly Demand of Diesel oil, Countrywide



This "Rabi factor" expresses the additional demand generated in the winter time for irrigation. It has obviously a strong impact on the storage (and send out) requirements of these depots that are meant to meet the irrigation needs of the agricultural sector, such as Baghabari, Parbotipur, and the Western Group, as well as the three transfer depots. These transfer depots supply over 90% of the demand in the Rajshahi Division: Godenail and Fatullah supply Baghabari by SDT while Daulatpur supplies Parbotipur and the Western Group by train.

Figure 4.9 shows the diesel volumes transferred by oil companies from their depots in Godenail, Fatullah and Daulatpur to the north-western depots in FY2009[32]. The peak is much more acute than in Fig. 4.8 due to the prevalence of agriculture in the diesel demand, and the Rabi factor is logically higher there than at country level.

[32] Godenail to Baghabari (Meghna), Fatullah to Baghabari (Jamuna), Daulatpur to Rajshahi and Natore (Padma). Jamuna transfers also include limited volumes sent to Chilmari and Sachna Bazar.

Figure 4.9 – Diesel Transfers to the North-western Area

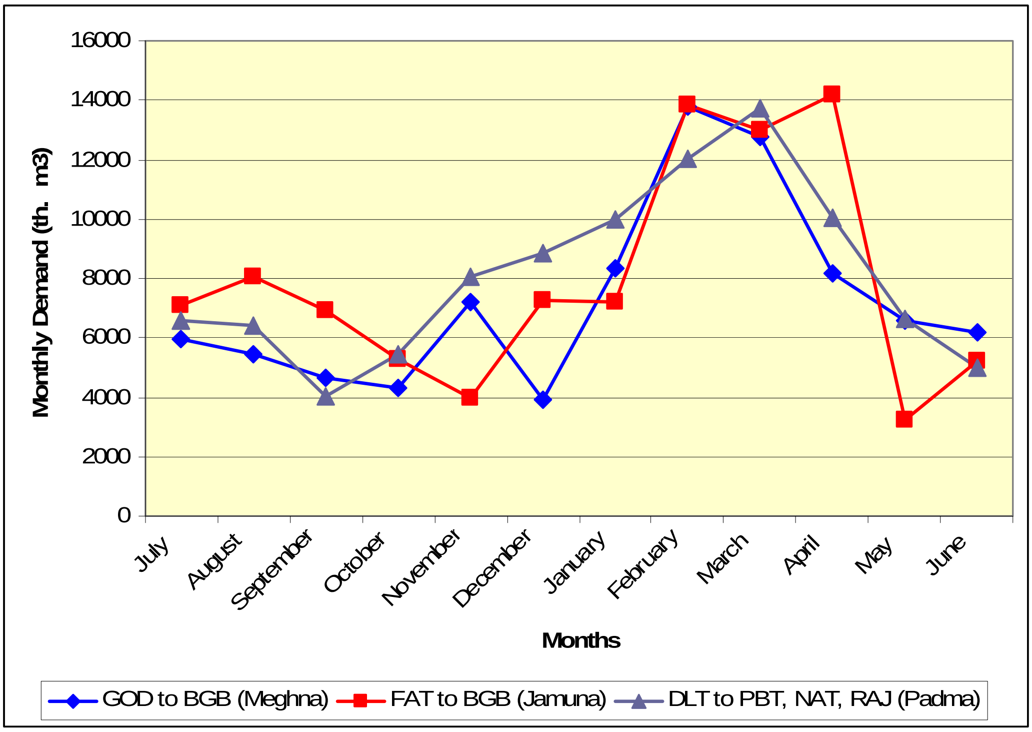


Table 4.10 - Rabi Factor (Winter Peak Demand, FY2009)

Rabi Factor	**Northwestern Area**	Country
Four-month average over yearly average	1.47	1.33
Peak month over yearly average	1.70	1.40
Four-month average over 8-month lower demand average	1.93	1.59
Peak month over 8-month lower demand average	2.22	1.68

The additional winter demand has a major impact on the storage requirements, in particular in the transfer depots where the number of ASD is already low. The number of ADS is estimated to fall to about **4 days at the Godenail and Fatullah** depots, and **6 days at Daulatpur** (in average for the 3 companies).

1.4. Jet Fuel

Most jet fuel is consumed at Dhaka airport, with smaller quantities at Chittagong and Jessore. The Chittagong 1,000-ton airport depot is easily supplied by tank lorry from the MI and, despite a low ASD (8 days) this seems sufficient; the 415-ton Jessore depot covers 6 months of supply (in FY2009-2010).

The Dhaka airport depot (known as 'KAD') has a capacity of 2,900 tons. It is supplied by tank lorries from Padma's Godenail depot, where the jet fuels tanks have also a capacity of 2,900 tons. The distance between Godenail and KAD is about 40 km, and it takes 2 hours to cover the distance. It takes about 90 to 100 movements of 9,000-liter lorries to supply the average daily demand of the airport. It may take up to 140 movements during the Hajj period.

With a combined capacity of 5,800 tons for an average daily demand of about 650 tons, the combined ASD is close to 9 days. However, two factors tend to seriously downgrade the real efficiency of the depots: first, the responsiveness of two depots located 40 km away is not as high as that of a single depot[33]; second, during the Hajj the daily demand reaches 1,000 to 1,100 tons/day, which reduces the combined ASD to 5 to 6 days, with **less than 3 days at either Godenail or KAD.**

2. Geographical and product-wise repartition

Whatever their storage capacity, the geographical breakdown of the 22 storage sites is quite imbalanced throughout the country. While the eastern and north-eastern areas look over-equipped, with 8 storage sites from Chandpur to Sachna Bazar, there is only one storage site in the South (Chittagong), one in the Khulna Division (Daulatpur), and none in the North (e.g. Mymensingh). Also, the Dhaka area, in spite the two large-size depots of Godenail and Fatullah, remains under-equipped, as evidenced by the low ASD ratio.

A second factor that tends to constrain the security of supply and the storage efficiency is the fact that not all products are available at each depot, even among the main six ones. While diesel oil is available in every depot, and kerosene almost everywhere, motor gasoline – whether regular or premium – is far from being available at every storage site.

As a result, 8 storage sites do not store regular gasoline, and 2 more do not store premium gasoline. Where required these products have to be supplied by tank lorry, sometimes over long distances, a less efficient and more expensive means of transport. The lack of gasoline storage is particularly acute in the Northwest, where only Baghabari, located in the far south-eastern corner of the Rajshahi Division, over 200 km away from Rangpur and Parbotipur, is equipped with reasonably-sized gasoline tanks.

Fuel oil storage is even scarcer, as only the Dhaka area depots and Daulatpur are equipped to store it. This should not create a major problem in respect of the FO volumes intended for feeding power plants, as these are generally equipped with their own storage facilities. Conversely, should fuel oil needs increase for the industrial sector due to the gas crunch, which is more than likely, then fuel oil storage will need to be developed.

[33] Except in the occurrence of a major problem right in the depot.

Table 4.11 - Storage Capacity Summary and Product-wise Breakdown

		Type	HOBC	MS	SKO	HSD	FO	JET	TOTAL
Southeast	Chittagong-MI	Main Installation	9,533	16,863	47,596	114,459	36,620	24,220	**249,291**
Dhaka and the East	Godnail	Large	1,210	1,100	2,260	7,530	2,040	2,900	**17,040**
	Fatullah	Large	1,546	1,664	2,052	7,589	1,076		**13,927**
	EPOL Dhaka	Security storage	560	310		2,600			**3,470**
	Chandpur	Small	30	593	3,261	4,937			**8,821**
	Ashuganj	Small			755	1,855			**2,610**
	Bhairab	Small			1,383	1,665			**3,048**
Northeast	Sylhet	Railhead	84	448	1,471	1,822			**3,825**
	Mogla Bazar	Railhead	221	310	280	280			**1,091**
	Sachna Bazar	Barge			195	209			**404**
	Sreemongal	Railhead	394	581	972	1,533			**3,480**
	B Baria	Railhead		30		165			**195**
Northwest	Baghabari	Large	458	1,799	4,113	33,042			**39,412**
	Parbatipur	Railhead		313	937	8,712			**9,962**
	Rangpur	Railhead	35	30	1,366	1,778			**3,209**
	Balashi	Barge			87	97			**184**
	Chilmari	Barge			194	662			**856**
	Natore	Railhead			130	870			**1,000**
	Harian	Railhead, no storage							
	Rajshahi	Railhead, no storage							
Southwest	Daulatpur	Large	1,020	2,340	4,580	17,383	3,746	415	**29,484**
	Barisal	Small		143	1,915	4,526			**6,584**
	Jhalakati	Barge		380	1,005	1,797			**3,182**

3. Transportation

All oil products leaving the Chittagong MI to other depots (except Chittagong airport) are transported by sea and riverways. Marine transport accounted for 93% of the 2.9 million tons dispatched from the MI in FY2009-2010, leaving a thin 7% to rail. In addition to that primary transport 0.6 million tons are transported from the three transfer depots to regional depots downstream, there again either by river in SDT (0.3 million) or by train (0.3 million).

In total (Table 4.12) about 3.5 millions tons were moved by ship or rail in FY2009-2010, with marine transport accounting for 86% and rail for 14%.

Table 4.12 – Oil Products Flows, by mode (FY2009-2010)

	Marine (tons)	%	Rail (tons)	%	Total (tons)
From Chittagong – MI to all destinations	2,691,782 (coastal tanker[34])	*93*	202,032 (meter gauge)	*7*	2,893,814
From Godenail / Fatullah to Baghabari, Chilmari, Balashi and Sachna Bazar	282,364 (shallow draft tanker)	*100*			282,364
From Daulatpur to Parbotipur, Rajshahi, Natore, Harian			294,186 (broad gauge)	*100*	294,186
Total	2,974,146	*86*	496,218	*14*	3,466,464

Transportation from the MI to the depots is done by waterways or by rail. Tank lorries only take care of the final (retail) distribution activity, and supply the airport depots of Dhaka and Chittagong. Each MI has its own send-out facilities, a Dolphin jetty (Meghna and Padma) or pontoon jetty (Jamuna) for coastal tankers and a dedicated siding for tank wagons.

3.1. Marine Transport

3.1.1. Routes and Vessels

There are 8 marine routes from Chittagong to regional depots. Three trunk routes to Godenail, Fatullah and Daulatpur account for 80% of the total volumes transported. They supply the main depots that serve the larger demand of the Dhaka (through Godenail and Fatullah) and Khulna (through Daulatpur) areas. They also constitute the first leg of the combined supply routes to these areas that cannot be reached by coastal tankers due to limited draft, in particular in the Northwest. Thinner routes carry the products from MI to Barisal, Jhalakati, Chandpur, Ashuganj and Bhairab.

[34] Except 52,000 tons transported from MI to Baghabari by seagoing SDT.

Regular traffic is performed by **coastal tankers**. These are small-size vessels designed to carry up to 1,600 tons of products, though the real available capacity usually ranges from 1,000 to 1,200 tons. They are capable of crossing the Bay of Bengal and can travel on rivers of Class I (see Table 4.13 below) as they require a minimum draft of 12 feet (3.66 meters).

While a few ships belong to the oil companies or BIWTC[35], the vast majority belong to, and are operated by private owners contracted by the oil companies. The operators are paid according to the actual load carried and the distance covered. Oil companies have 80 coastal tankers under operation, but not all of them are in good seaworthy conditions.

Table 4.13 – Marine Fleet

	JAMUNA	MEGHNA	PADMA	*TOTAL*
Number of coastal tankers	29	25	26	80
Average capacity (tons)	1,178	1,064	1,331	1,192
Number of SDT	9		6	
Average capacity (tons)	542		588	

Voyages downstream the transfer depots are operated by **shallow draft tankers** (SDT). These smaller vessels are designed to carry up to 600 tons. The useful capacity is usually around 500 tons. They are not capable of crossing the Bay of Bengal, except some SDT that have been certified for seagoing operation and are used to supply additional diesel quantities from MI to Baghabari without transferring at Godenail or Fatullah. They require a minimum draft of 7 feet (2.13 meters) and can travel on rivers of Class I and II.

Table 4.14 – Marine Routes

Route	Type of vessel	Flows (thousand tons in FY2009-2010)	Average Monthly Frequency[36]
From **MI** to:			
Godenail	Coastal Tanker	881	70
Fatullah	Coastal Tanker	517	41
Chandpur	Coastal Tanker	145	12
Ashuganj	Coastal Tanker	48	4
Bhairab	Coastal Tanker	120	10
Baghabari	Shallow draft	52	8
Daulatpur	Coastal Tanker	891	71
Barisal	Coastal Tanker	101	8
Jhalakati	Coastal Tanker	82	7
From **Godenail** / **Fatullah** to:			
Baghabari	Shallow draft	267	40
Chilmari	Shallow draft	4	<1
Balashi	Shallow draft	--	--
Sachna Bazar	Shallow draft	11	2

[35] Bangladesh Inland Waterways Transport Company (state-owned).
[36] Based on 1,050 tons cargoes for coastal tankers, and 550 tons for SDT.

3.1.2. The Waterways System

The total length of the Bangladesh waterway system (700 rivers) is about 13,000 km. Of this, 8,400 km are navigable by larger vessels in the rainy season (6,000 km of which is classified for navigation) while in the dry season about 4,800 km are navigable (3,865 km classified).

The inland navigable waterway routes as classified by BIWTA fall into four groups:

Table 4.15 – Inland Waterways Classes

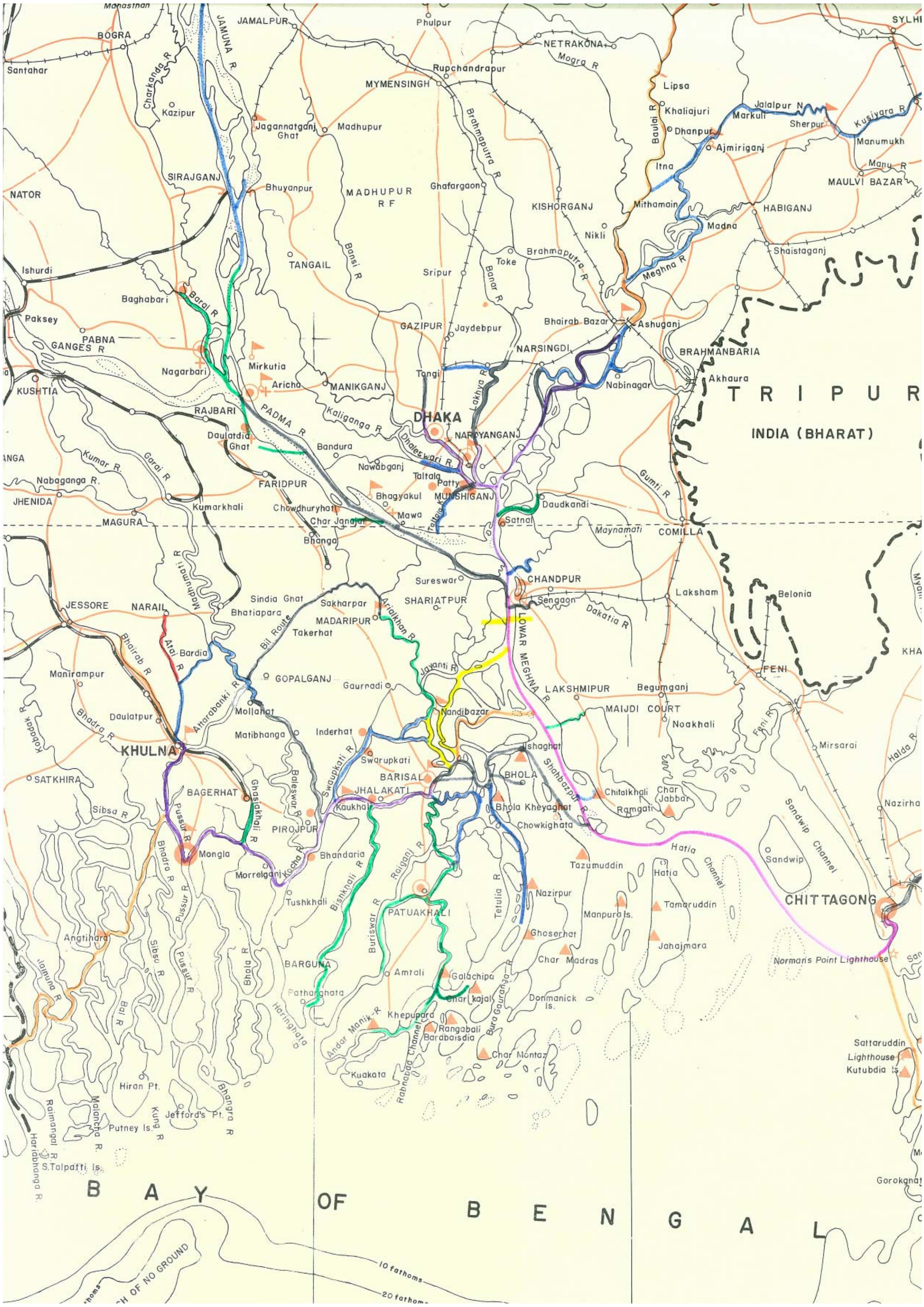
Name of Route	Minimum Depth	Length of Route and Percentage (wet season)
Class- I	3.66 m (12 ft)	683 km (11%)
Class- II	2.13 m (7 ft)	1,027 km (17%)
Class -III	1.52 m (5 ft)	1,885 km (32%)
Class -IV	Less than 1.52 m	2,400 km (40%)
Total		5,995 km

Source: BIWTA

Figure 4.16 – Main Inland Waterways Routes

Class-I:	Four trunk routes: • Chittagong-Chowkighata-**Chandpur**-Shambhupura-**Narayanganj**[37]/ Dhaka; • Shambhupura-Demra; • Shambhupura-**Bhairab Bazar/Ashuganj**; and • Chowkighata-**Barisal**-Mongla-**Khulna**-Maheswarpasha.
Class-II:	Eight link routes: • Mohanpur-Daikhawa; • Bhairab Bazar-Chhatak; • Chalna-Raimongal; • Hijla-Saistabad; • Satnal-Daudkandi; • Chittagong-Cox's Bazar; • Diara-Barisal via Nandir Bazar; and • Chandpur-Ichuli.

[37] Narayanganj is the District of the Godenail and Fatullah depots.


DHAKA
NARAYANGANJ
KHULNA
CHITTAGONG
BARISAL
CHANDPUR
MYMENSINGH
COMILLA
INDIA (BHARAT)
T R I P U R
BAY OF BENGAL
PADMA R
LOWAR MEGHNA R
JAMUNA R
Brahmaputra R
Meghna R
Mongla
PATUAKHALI
FARIDPUR
JESSORE
SIRAJGANJ
TANGAIL
GAZIPUR
NARSINGDI
Ashuganj
BRAHMANBARIA
Bhairab Bazar
KISHORGANJ
NETRAKONA
HABIGANJ
MAULVI BAZAR
FENI
Noakhali
LAKSHMIPUR
BHOLA
BAGERHAT
PIROJPUR
BARGUNA
GOPALGANJ
MADARIPUR
MUNSHIGANJ
MANIKGANJ
RAJBARI
KUSHTIA
PABNA
BOGRA
JAMALPUR
Normans Point Lighthouse
Sandwip Channel
Hatia
Kutubdia Is
Sattaruddin Lighthouse

3.2. Bottlenecks

River transport faces several obstacles, in particular during the dry season. Siltation and lack of appropriate dredging hamper the conditions of navigation, including on Class-I and Class-II rivers. Newspapers routinely report on boats and launches stuck on shoals for days and weeks (see Box below). In spite of recurrent announcements by the Inland Water Transport Authority (BIWTA) stating that new dredges are scheduled for delivery, dredging of both river channels and landing ghats does not meet the specifications of the minimum guaranteed depth, whatever the river Class. Low tide combines with inadequate dredging to often make unloading at Daulatpur impossible for several hours.

Box 4.17 – Baghabari Port Inaccessible

No vessels and barges loaded with fertilizers, fuel and rice could reach Baghabari port for the last 18 days due to poor navigability in the Jamuna River, and thereby virtually brought the activities of the port into a halt. Sources said that a total of 32 vessels and barges remained stuck at shoals in different places of the river, disrupting supply of the essentials through the port.

The river channel has become unfit for cruising of the cargo vessels as a large number of shoals have emerged for lack of proper dredging in the river. Baghabari Depot of Bangladesh Petroleum Corporation sources said that 17 shallow draft tankers with 62 lakh litres of fuel oil and another 15 vessels with fertilizer and other essential items got stuck at Shibalaya of Manikganj, and Penchakhola, Mohanganj, Nakalia and Koitola under Pabna district.

Boro cultivation will be badly hampered in the northern region as the supply of fertilizer and fuel is being affected with the navigability problem. The depot sources said on an average 27 lakh litres of fuel oil, mostly diesel, are being supplied to 16 districts of the region daily. The daily demand for diesel in current Boro season in the region is 20-22 lakh litres.

As the vessels and barges with fuel oil cannot reach the port due to poor navigability of the river, fuel oils are being supplied to the region from reserve stock. There are about 2.58 crore litres of fuel reserved in distribution centers of Padma, Meghna and Jamuna companies by which only 12 days' demand could be met.

"There will be a fuel crisis if the navigability problem cannot be solved by this time," said the sources. Abdur Razzaque, Assistant Director of Bangladesh Inland Water Transport Authority (BIWTA) at Baghabari river port, said they have already sent letters informing the higher authorities about the present situation of the port as well as recommending dredging in the river.

Source: dredgingtoday.com, 25 January 2010

3.3. Tankers Operation

If there is one area in the oil industry where shortage is not – currently – a threat, it is coastal tankers operation. A preliminary analysis of the routes and volumes transported show that there are about twice as many coastal tankers as really needed. Every ship operates in average 30 round trips per year, though it could easily operate 50 to 60 trips. Ship oversupply put the oil companies under pressure from the tankers owners to have tankers sent out of MI to depots that do not really require it because there is no space left in the tanks. Four of five tankers can often be seen waiting in line for unloading at depot jetties. They are recorded in BPC charts as 'floating storage'.

Table 4.18 presents the estimated tankers requirements for FY2009-2010.

Table 4.18 – Coastal Tankers Requirements[38] (FY2009-2010)

Routes, from MI to:	Volumes transported (thousand tons)	Days required for one round trip	Number of yearly round trips	Number of tankers required
Godenail / Fatullah	1,406	5	1,339	20
Chandpur	146	4	139	2
Ashuganj / Bhairab	168	6	160	3
Daulatpur	884	7	842	18
Barisal / Jhalakati	184	5	175	3
Total	2,484		2,366	45

The situation, however, is likely to evolve rapidly, as transport requirements are rising due to the rapid implementation of power plants under the Quick Rental Programme. The maximum carrying capacity of the existing coastal tankers fleet is estimated at 5 millions tons per year, a figure that is expected to be reached in FY2013.

3.4. Railways

Bangladesh Railways has transported 500,000 tons of oil products in FY2009-2010. Oil products account for about 15% of the total freight moved by the operator.

3.4.1. Routes and Equipment

Oil products are transported by rail to these depots that are not accessible by river. The oil companies use the two railway systems operating in Bangladesh:

The **meter gauge** (MG) system in the East, supplies from Chittagong-MI the Northeastern depots of Sylhet and Srimongal on a regular basis, although Sylhet may receive part of the cargoes by SDT from Godenail / Fatullah. Chandpur is supplied by coastal tankers and rail. Local power stations in the Northwest are also supplied through the MG system, including Rangpur PS (from Chittagong) and Thakurgaon PS (from Parbotipur). In the Dhaka area the emergency depot (EPOL) receives oil products by rail from MI.

The **broad gauge** (BG) system in the West, from Daulatpur to Parbotipur and the Western Group (Rajshahi, Natore and Harian), as well as to power stations at Bheramara and Sayedpur.

The borderline between BG and MG is fading, as BR is developing dual gauge (DG) tracks, in particular west of Dhaka. Dhaka can now be reached from Daulatpur through a seamless BG track across the Jamuna Bridge, opened in 1998. In the Northwest, the upgrading to dual

[38] Assumptions: Average load transported: 1,050 tons per coastal tanker. Ship availability: 330 days per year.

gauge of both the meter gauge section between the Jamuna bridge and Ishwardi and the broad gauge section between Ishwardi and Parbotipur has allowed to supply Rangpur, which is not connected to the BG line, as well as Parbotipur through a seamless connection from Chittagong.

Shipments are organized in block trains (“racks”) of 24 to 30 wagons that may belong to different oil companies. Oil products are transported in tanker wagons of various sizes.

Table 4.19 – Tanker Wagon Types

Wagon Type	Volume (liters)	Capacity (tons, middle distillates)
Broad gauge:		
• BTO	50,000	40
• BTM	32,000	25
• BTP	28,000	22
Meter gauge:		
	32,000	25
	21,000	16.5

The capacity of a rack train depends on several factors: track gauge, number, and types of wagons. On the BG system, trains to Parbotipur typically consist of 30 BTO and BTM wagons, with a capacity of 1,000 tons. Trains to Natore, Rajsahi and Harian are shorter, and include a higher proportion of smaller-size BTM and BTP wagons. Their capacity is estimated at 720 tons per train. There is about one daily train in average that leaves Daulatpur to upnorth depots. Frequency increases significantly during the winter season, with up to two daily trains between January and April.

MG rack trains are smaller. Their capacity is typically 500 to 600 tons. There is one daily train in average that leaves the main installations.

Table 4.20 – Railway Routes

Route	Railway System	Estimated throughput (th. tons)	Comments
From **MI** to:			
Sylhet	Meter gauge	79	Some volumes carried by SDT from Godenail/Fatullah
Srimongal	Meter gauge	56	
Chandpur	Meter gauge	<1	
EPOL	Meter gauge	27	
Rangpur	Meter gauge	20	
Parbotipur	Meter gauge	11	Only MS and some HSD
		194	
From **Daulatpur** to:			
Parbotipur	Broad gauge	194	HSD and SKO
Rajshahi	Broad gauge	36	
Natore	Broad gauge	52	
Harian	Broad gauge	14	
		296	

3.4.2. Bottlenecks

There are about 1,000 tanker wagons on the two systems. However, all oil companies state that Bangladesh Railways (BR) permanently lack engines and wagons, and sometimes drivers, to satisfactorily meet the demand, in particular the higher volumes required in the dry season. Indeed, BR reports fairly low rates of technical availability for the wagons ('percentage of wagons available for use'), with 74% on the BG network and 86% on the MG network.

In respect of unmet requirements, the meter gauge system is reportedly more affected than the broad gauge line. As a result, some depots, e.g. Rangpur, which is currently only connected to the MG system and is supplied by direct trains from MI, are currently under-utilized due to lack of transport capacity.

Some positive moves are underway. The development of dual-gauge tracks, which enable both BG and MG trains to use the same tracks through the implementation of a third rail, has been completed on both sides of the Jamuna bridge, enabling seamless connections from Chittagong to the Northwest. However, while Parbotipur can now be reached by both BG trains from Daulatpur and MG trains from Chittagong, there remains to complete the short, 50 km-long section between Parbotipur and Rangpur, which will allow the Rangpur depots to also receive direct BG trains from Daulatpur.

In the eastern (MG) system, the doubling of the Chittagong-Tongi-(Dhaka) line is partly done. This is the most important transportation corridor in the country: forming only 15% of BR's route-km, it carries 49% of freight-km. Traffic demand is expected to significantly increase on this route with the development of containers trains, one of BR's priorities.

Out of the 312 km-long line, three double-track sections already comprise 116 km. There remains to double-track the 64 km-long Tongi-Bhairab section -- the second highest traffic density of the BR network – and the 132 km-long Akhaura-Chinki Astana, i.e. 196 km in total. The doubling will increase train running capacity tremendously, at least double the 20 trains each way at present running between Chittagong and Dhaka, and also increase the capacity of traffic from/to Chittagong and the Northeast. In particular, it will de-bottleneck the Tongi-Bhairab-Akhaura section, saturated with 42 daily trains.

As a result of the doubling of the line, the commercial speed[39] of the freight trains should significantly increase. At 16.2 km/h on the MG network, it takes currently about 20 hours to connect Chittagong to Dhaka or Sylhet. The commercial speed on the BG line is even worse, at 10.8 km/h[40].

Table 4.21 – Capacity and Throughput on the Dhaka-Chittagong Line

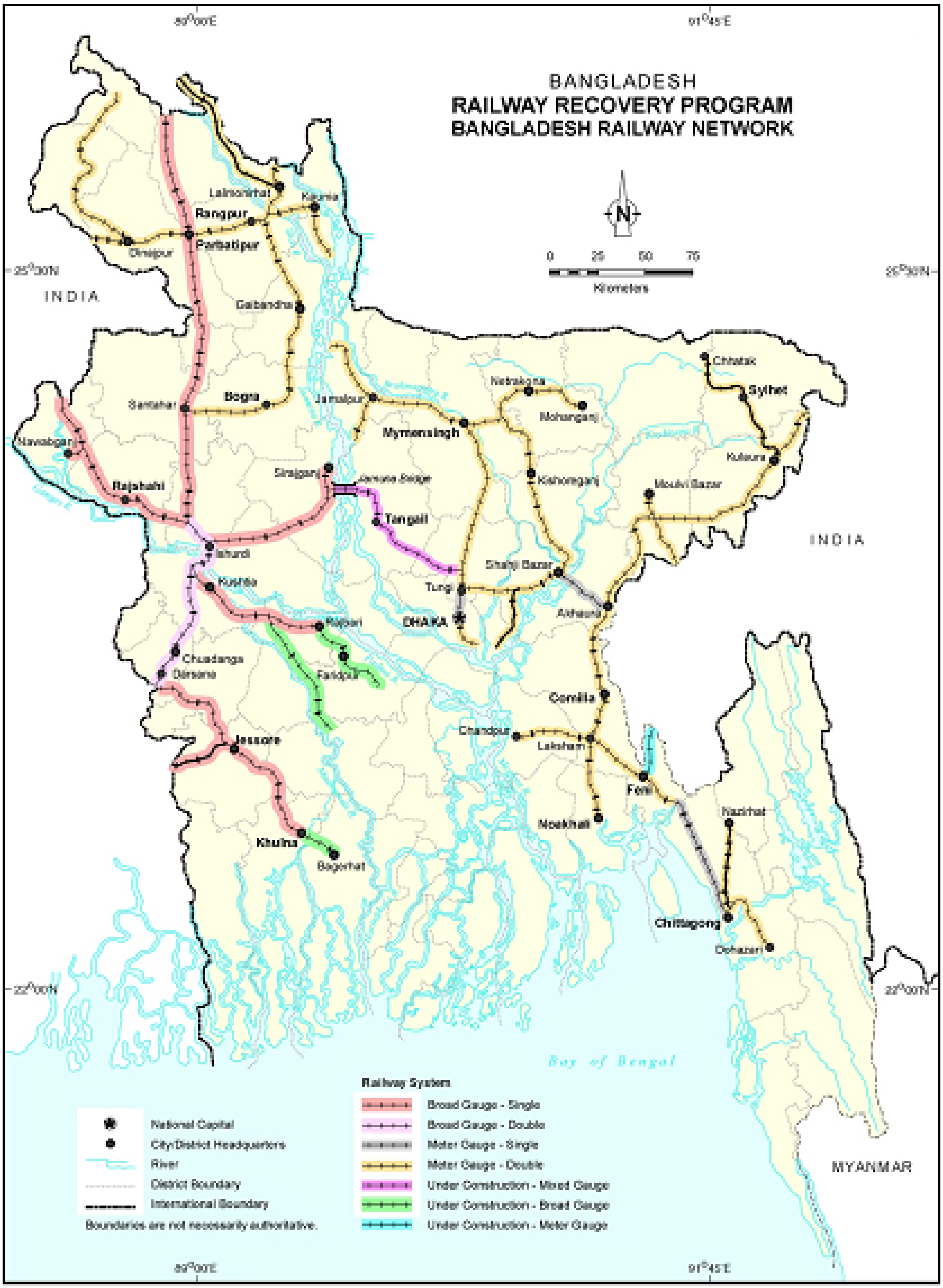
Section	Dist. (km)	Number of daily trains				Sectional Capacity	**%** *utilization*
		Passeng.	Container	Bulk freight	Total		
Dhaka-Tongi	23	58	5	3	66	106	*62*
Tongi-Bhairab	64	34	5	3	42	42	*100*
Bhairab-Akhaura	24	34	5	3	42	n/a	*n/a*
Akhaura-Chittagong	201	28	5	6	39	48	*81*

Source: ADB, Regional Rail Traffic Enhancement Project, 2005

[39] Commercial speed qualifies the average speed of a vehicle from the time it leaves its origin to the time it arrives at destination. It includes all stops and pauses on the way, whatever the cause.
[40] Source: Bangladesh Railway, quoted in the BSS Statistical Yearbook.

In respect of rolling stock, the Executive Committee of the National Economic Council (ECNEC) has recently approved the procurement of 10 BG locomotives for BR and 180 BG oil tankers, and discussions are underway with Indian Railways for the rental of additional engines.

Map of Bangladesh Railways



Source: ADB

Note: The Jamuna Bridge-Ishwardi-Parbotipur sections are now dual-gauge.

3.5. Transportation Cost

Transportation costs, whether marine or railways, are fixed by the Government. They are maintained at a low level to keep the overall delivery cost of products low.

3.5.1. Waterways

Marine freight rates are set at 1.60 and 2.17 Taka per ton*km (2.97 and 4.02 Taka per ton*nautical mile) for coastal tanker and SDT, respectively.

Table 4.22 – Marine Tanker Freight Rates

From	To	Distance	Rate (Tk)		Rate (USD)
		Nautical Mile	Per Ton*N. Mile	Per Ton	per MT
Coastal tankers (1,500 MT)					
Chittagong	725 - Godenail	181	2.97	538	7.74
Chittagong	730 - Fatullah	181	2.97	538	7.74
Chittagong	721 - Daulatpur	265	2.97	787	11.33
Chittagong	722 - Jhalkati	161	2.97	478	6.89
Chittagong	733 - Barisal	142	2.97	422	6.07
Chittagong	727 - Bhairab	231	2.97	686	9.88
Chittagong	726 - Baghabari	224	2.97	665	9.58
Chittagong	738 - Chilmari	326	2.97	968	13.94
Chittagong	720 - Chandpur	149	2.97	443	6.37
Shallow Draft Tankers (350-600 MT)					
Godenail / Fatullah	726 - Baghabari	119	4.02	478	6.89
Godenail / Fatullah	738 - Chilmari	237	4.02	953	13.72
Godenail / Fatullah	727 - Bhairab	62	4.02	249	3.59
Godenail / Fatullah	Sachna Bazar				
Godenail / Fatullah	720 - Chandpur	50	4.02	201	2.89
Godenail / Fatullah	739 - Nagarbari	103	4.02	414	5.96

Source: own calculations, based on published freight rates

3.5.2. Rail

Rail freight rates follow a more complex structure that includes:

- a route fee, in Taka per kg, that varies with the distance, but not strictly proportionally,
- for a given destination, the route fee varies according to the type of product transported (light products, such as motor fuels, are more expensive than distillates on a per kg basis, due to lower specific gravity),
- siding charges at origin and destination are generally added, but not systematically; they apply to each wagon, irrespective of the payload.

Table 4.23 – Railways Freight Rates

From	To	Type of depot	Distance (km)	Rate, per ton (Tk)	Rate, per ton (USD)
Broad gauge, Daulatpur/Khulna to northern depots					
Daulatpur	Rajshahi	Railhead	303		
Daulatpur	Natore	Railhead	279	434	6.25
Daulatpur	Harian	Railhead	295	434	6.25
Daulatpur	Parbotipur	Transfer	419	528	7.60
Daulatpur	Bheramara	Power plant	185	344	4.95
Daulatpur	Sayedpur	Power plant	433	511	7.35
Meter gauge (all other routes)		Type of product	Distance (km)	Rate, per ton (Tk)	Rate, per ton (USD)
Chittagong	Srimongal	MS / HOBC HSD / SKO	294	524 444	7.55 6.40
Chittagong	Sylhet	HSD / SKO	381	484	6.97
Chittagong	Mogla Bazar	HSD / SKO	370	484	6.97
Chittagong	EPOL, Dhaka	MS / HOBC HSD / SKO	335	617 507	8.89 7.30
Chittagong	Rangpur	HSD / SKO	800	719	10.35
Chittagong	Parbotipur	MS / HSD	761	1,080	15.55
Chittagong	Chandpur	HOBC/SKO/HSD/JBO	183	344	4.96

Source: own calculations, based on published freight rates. 1 USD = 69.45 Tk.

3.5.3. Road

The only road route is the link between Padma's depot at Godenail and the KAD depot at Dhaka airport. The freight rate is 2,250 Takas per trip for a 9,000-liter tank lorry over a distance of about 40 km, i.e. 4.50 USD/ton.

3.5.4. Route-wise Costs

Table 4.24 overleaf shows the combined freight rates for the various supply routes, in Takas per ton.

		Water		Railway		Water + Railway		Water + Lorry	
	Type of Product	Cost (Tk)	Type of vessel	Cost (Tk)	Type of rail track	Cost (Tk)	Combined Means of Transportation	Cost (Tk)	Combined Means of Transportation
FROM CHITTAGONG (MI) TO:									
DHAKA AREA									
Godenail / Fatullah		538	Coastal						
Airport (KAD)	Jet A-1							850	Coastal + Lorry
EPOL	MS / HOBC			617	Meter gauge				
	HSD			507	Meter gauge				
Chandpur	HOBC, MS, HSD, SKO	443	Coastal						
	JBO			344	Meter gauge				
Ashuganj	HSD, SKO								
Bhairab Bazar	HSD, SKO	787	Coastal						
SOUTHWEST AND NORTHWEST									
Daulatpur (Khulna)	All	787	Coastal						
Natore	HSD, SKO					1,221	Coastal+Broad		
Harian	HSD, SKO					1,221	Coastal+Broad		
Rajsahi	HSD, SKO						Coastal+Broad		
Parbotipur	HSD, SKO					1,315	Coastal+Broad		
	MS, some HSD			1,080	Meter gauge				
Rangpur	HSD, SKO			719	Meter gauge				
Balashi			Coastal+SDT						
Chilmari	HSD	1,490	Coastal+SDT						
Baghabari	HOBC, MS, HSD, SKO	1,016	Coastal+SDT						
Barisal	MS, HSD, SKO	422	Coastal						
Jhalkati	MS, HSD, SKO	478	Coastal						
NORTHEAST									
Sylhet	HOBC, MS, HSD, SKO			484	Meter gauge				
Srimongal	MS, HOBC			524	Meter gauge				
	HSD, SKO			444	Meter gauge				
Mogla Bazar	HSD, SKO			484	Meter gauge				
Brahman Baria	HSD, SKO	from local plant							
Sachna Bazar (Chattak)	HSD, SKO		Coastal+SDT						

Source: own calculations, based on published freight rates where available

Bangladesh

Asian Development Bank

STRENGTHENING OF THE HYDROCARBON UNIT IN THE ENERGY AND MINERAL RESOURCES DIVISION (PHASE-II)

REFINING AND MARKETING

RFP HCU/CS-06

HSE ASSESSMENT REPORT

SOFRECO

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Société Française de Réalisation, d'Etudes et de Conseil
92-98, boulevard Victor Hugo 92115 Clichy Cedex - France
Tél : +33 1 41 27 95 95 - Fax : +33 1 41 27 96
E-mail : infra@sofreco.com - Site Web : www.sofreco.com

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1. HSE - REFINERY

Refineries are industrial sites that manage huge amounts of raw materials and products and they are also intensive consumers of energy and water used to carry out the process. In their storage and refining processes, refineries generate emissions to the atmosphere, to the water and to the soil, to the extent that environmental management has become a major factor for refineries. The refining industry is a mature industry and pollution abatement Programmes have been carried out in most refineries for a long time to different extends. As a result. the emissions generated by refineries have declined per tonne of crude processed and are continuing to decline.

An emission inventory is a comprehensive list or data base of atmospheric and other emissions (by component, in kg/h) from the individual sources. It is the starting point of a formalised and effective process of continuous improvement. In many countries emission inventories are a legal requirement.

The emission flow rates from the inventory can be used to compare the applied techniques with other refineries, i.e. with international “best available technology (BAT)” or “state-of-the-art” data.

The “BAT” concept can be described as:

- “Best” for the protection of the environment and society as a whole.
- “Available” thus allowing implementation, under economically and technically viable conditions, taking into consideration the costs and benefits.
- “Techniques” can mean technology, design and construction, but also maintenance, operating procedures, commissioning and decommissioning procedures. It is thus a wide term, designed to include all factors relevant to the environmental performance of an installation.

For the European Union BAT is described in so-called BAT Reference documents [BREF] that are published by the European Commission. There are similar documents also in the USA.

The assessment in this study follows a „risk-based“ approach - i.e. mitigation measures according to BAT are not required simply because the technique is available but only if there is a need for controls based on the scientifically established environmental quality objectives and risk assessments, related to the use of the environmental compartments. A refinery located at a remote location need not comply with the same requirements as a refinery that is located in a city. This environmental risk assessment is performed by assessing not only the actual emission of the refinery but also its contribution to the overall pollution.

1.1. Emissions to the atmosphere

At ERL a comprehensive emission inventory was not in place. To assess the environmental impacts of the refinery operation an emission inventory was drawn up based on best estimates for the individual sources (table 2). The basis of estimation of the individual emission components is explained in paragraph 1.1.3 and following.

Power plants, boilers, heaters and catalytic cracking are the main sources of emissions of carbon monoxide and dioxide, nitrogen oxides (NOx) particulates and sulphur oxides (SOx) to the atmosphere. Refinery processes require a significant amount of energv - approximately 2 % of the total throughput. More than 60 % of refinery air emissions are related to the production of energy for the various processes. Sulphur recovery units and flares also contribute to those emissions. Catalyst changeovers and cokers release particulates. Volatile organic compounds (VOC) are released from storage, crude and product loading and handling facilities, oil/water separation systems and from flanges, valves. seals and drains.

Table 1 shows a very brief summary of the main pollutants emitted by a refinery. with their main sources.

Table 1: Main refinery pollutants	
Air pollutants	**Sources**
nitrogen oxides	process furnaces, boilers, gas turbines sulphur recovery units flares, incinerators
particulates	process furnaces, boilers, gas turbines FCC crackers coke calciners incinerators, flares
sulphur oxides	process furnaces, biolers, gas turbines FCC crackers coke calciners incinerators, flares
volatile organic compounds (VOC)	storage and handling facilities oil water separation fugitive emissions (valves, flanges etc.) vents, flare

1.1.1. Quantification and assessment of ERL emissions

The emission inventory of the ERL refinery is shown in table 2.

Table 2: Air emissions inventory ERL

tag #	type	unit	fuel	thermal	flue gas	emission concentration		emission flow rate		
				capacity		mg/m³		kg/h		
				MW	m³/h	NOx	SOx	NOx	SOx	VOC
F-1101	furnace	crude distillation	fuel oil	29,60	29.600	300		8,88	79,92	
F-1201	furnace	cat ref pretreatment	ref gas	0,97	970	250		0,24	0,39	
F-1202	furnace	cat ref pretreatment	ref gas	0,72	720	250		0,18	0,29	
F-1203	furnace	cat ref	ref gas	0,52	520	250		0,13	0,21	
F-1204	furnace	cat ref	ref gas	0,93	930	250		0,23	0,37	
F-1205	furnace	cat ref	ref gas	3,29	3.290	250		0,82	1,32	
F-1301	furnace	hydrotreater	nat gas	2,60	2.600	250		0,65		
BA-3001	furnace	visbreaker	nat gas	17,20	17.200	250		4,30	92,88	
	furnace	hydrogen unit	nat gas	2,40	2.400	250		0,60		
10-F-01	furnace	Vac unit +asphalt unit	nat gas	6,60	6.600	250		1,65		
	incinerator	asphalt unit	nat gas	0,50	500	250		0,13		
	flare	flare	flare gas	0,50	500	250		0,13	0,20	5
	steam boiler 1	utilities	nat gas	10,00	10.000	250		2,50		
	steam boiler 2	utilities	nat gas	10,00	10.000	250		2,50		
	diesel generator	utilities	diesel	7,00	7.000	400		2,80		
	API separator	utilities								20
	crude storage	tank farm								20
	light products	tank farm								20

	storage									
	diffuse emissions	refinery								60
	total							**26**	**176**	**125**

The individual data and the way how they were estimated in described in the following paragraphs.

To allow for this assessment dispersion calculations are performed based on these emission flow rates. Dispersion calculations produce a model for ground level concentrations based on a certain emission flow rate.

Ground level concentrations are also covered by legal standards. The problem here is, that ground level concentrations stem from all kinds of emission sources in the relevant area and thus cannot be easily attributed to a certain source. Once ground level concentration limits are exceeded the consequence normally is that additional sources will not be permitted in the area and additional technical requirements might be imposed on existing ones to reduce the overall pollution.

Dispersion modelling is influenced by the source height and temperature and by the meteorological conditions - especially wind velocity and direction and the atmospheric stability. The latter conditions change continuously - therefore it is extremely important to consider appropriate averaging times. In the EU ground level concentrations are given as yearly average or as maximum hourly average.

The maximum hourly concentration can only be calculated based on meteorological data for each individual hour of a year. Such figures were not available - the calculations were performed on a yearly average basis. For continuously operating plants like a refinery the yearly average is completely sufficient to assess the relevance of an impact. Therefore, according to EU practice a plant is considered irrelevant, when its contribution to the ground level concentration is 3 % of the relevant limit.

The dispersion calculation thus aims at the question to what extent and in which area the refinery is a relevant contributor to the overall air pollution.

The calculation was performed for a grid of 20 x 500 m by 20 x 500 m, i.e. 10 x 10 km with a resolution 500 m. The results for the individual contaminants are shown on a map. The calculation was performed with the programme package AUSTAL, which has to be applied as a legal requirement in the permitting process in Germany [AUSTAL].

The relevant air emissions of a refinery comprise:

- SO_2 - sulphur dioxid
- VOC - volatile organic compounds
- NOx - nitrogen oxides
- particulate matter
- CO

CO has no actual relevance for the air quality because its concentration in the atmosphere virtually never exceeds relevant limits. Particulate matter is important when solid fuels are burnt - there are some particulates emissions from the firing of heavy fuel oil in the refinery also but it is not considered a relevant contaminant.

SO_2, VOC and NOx are assessed in more detail.

CO_2 is not a typical contaminant with a direct hazardous impact to air quality. It is considered as lead component for the greenhouse effect as a possible cause of global warming. CO_2 emissions are directly linked to the consumption of fossil energy in a refinery, i.e. the only reasonable way of mitigation is to increase the energy efficiency. This issue is covered in chapter xxx (refinery technology).

1.1.2. SO_2

Environmental relevance

Sulphur dioxide (SO_2) when emitted to the air can combine with water and form a component of 'acid rain'. The most relevant source of SO_2 is combustion of sulphur containing fuel especially motor vehicles within cities.

Refinery sources and best available mitigation techniques

SOx emissions from the refinery result directly from the combustion of sulphur contained in fuels. The fuel required for the raising of steam, or for the firing of heaters and furnaces, originates either from residual fuel oil or refinery gas both produced by the refinery itself or from natural gas that is bought from outside the fence. The refinery fuels are the by-products of the refinery processes. The composition and quality of these fuels, both gaseous and liquid fuels, vary with the crude oils processed.

All crude oils contain sulphur compounds. Consequently, when firing refinery fuels, SOx will be emitted. There is a direct relation between the sulphur content of the fuel and the amount of SOx emitted - by combustion the total amount of sulphur reacts to SO_2 irrespective of any differences between different combustion techniques. Pipeline quality natural gas normally contains only traces of sulphur compounds. In refineries with a higher complexity the FCC unit and the sulphur recovery are additional major sources of SOx emissions - ERL has no FCC and no sulphur recovery, the emitted SOx stems nearly completely from sulphur in fuel oil.

The SOx emission is only one restriction for refinery operation regarding sulphur. The other comes from the required product quality - especially the sulphur content in middle distillates. Reducing sulphur in middle distillates requires additional desulphurisation units in the refinery, thus increasing the heat demand and adding new SOx sources such as the incineration of high sulphur tailgases.

Table 3 depicts the development of the sulphur balance in European refineries from 1979 to 1995. It shows that in 1979 about 10 % of the total sulphur intake was emitted by the refinery and 75 % via the refinery products, whereas only a small amount was recovered. In 1995 sulphur in products was reduced considerably to about 40 % corresponding to a recovery rate of 36 %. The percentage emitted by the refinery was more or less stable.

Sulphur output category	% S intake 1979	% S intake 1982	% S intake 1985	% S intake 1989	% S intake 1992	% S intake 1995
S emitted by refinery as SO_2	9 [1)]	12.2	9.1	8.0	7.9	8.6
S in distillate S in fuel oil S in BFO	} } 75 [1)] }	} } 63.5 }	9.9 } 41.5 } 60.0 8.6 }	10.7 } 30.3 } 51.5 10.5 }	14.2 } 25.8 } 51.1 11.1 }	11.5 } 16.8 } 40.1 11.8 }
S emitted as SO_2	**84** [1)]	**75.7**	**69.1**	**59.5**	**59.0**	**48.7**
S fixed in special products [2)]	6 [1)]	10 [1)]	11.9	13.2	13.5	14.6
S recovered	10	14.7	19.0	26.9	27.1	36.3
S retained	**16**	**24.7**	**30.9**	**40.1**	**40.6**	**50.9**
TOTAL	100.0	100.0	100.0	99.6	99.6	99.6

Notes: (%w/w of total)
[1)]: Figures for the year 1979 from the first CONCAWE report (1979) are not accurate
[2)]: Chemical feedstock (naphtha), bitumen, coke, lube oil
Total sulphur intake in 1995 was 6.56 Mt.

Since fuel combustion is the main source of SOx emissions of a refinery, abatement techniques should be focused on the fuel. Given that there is a direct relation between the sulphur content of the fuel and the SOx emissions, abatement techniques consist of two types:

- decreasing the sulphur content of the fuel or
- flue gas desulphurisation

A decrease of the fuel sulphur content can be achieved by a (partial) switch to natural gas, a (partial) switch to low sulphur crude oil and refinery fuel desulphurisation. The first two options generally do not require large investments; the costs are operational costs related to the difference in costs for high sulphur and low sulphur crudes and fuels. When a connection to a natural gas grid is not readily available, a switch to low sulphur crude oils is the only low capital investment option.

The refinery fuel gas comes from different sources and is pooled in the refinery fuel gas system. Depending on the type of crude processed, the sulphur content of the untreated gas varies. Desulphurisation is achieved by amine scrubbing.

The liquid refinery fuel often consists of heavy residues, in which the sulphur of the crude is concentrated. Theoretically speaking it is possible to treat the liquid fuel in a hydrotreating process in order to remove the sulphur. However, because of the heavy fractions present in the liquid refinery fuel, much energy and large investments would be required.

Therefore, in most refineries a balance is made between the type of crude processed (high sulphur/low sulphur), the refinery fuel gas, natural gas and liquid refinery fuel. The ratio between these depends on local circumstances such as the refinery complexity and the production of fuel gas, an outlet to a chemical complex for the fuel gas and/or LPG recovery.

Most flue gas desulphurisation systems (FGD) use an adsorption or an absorption technique for the removal of SOx, either regenerative or non-regenerative. These systems are generally sensitive to other contaminants such as particulates, salts, sulphur trioxide etc.. This is a hurdle for FCC applications and may require a gas cleaning system upstream of the FGD. The SOx removed from the gas phase will have to be further treated or disposed of.

This can have an impact on the H_2S treating facilities or may generate an additional waste stream. Systems for flue gas desulphurisation are rarely applied on other refinery units than FCC regenerators.

ERL emissions and ground level concentrations

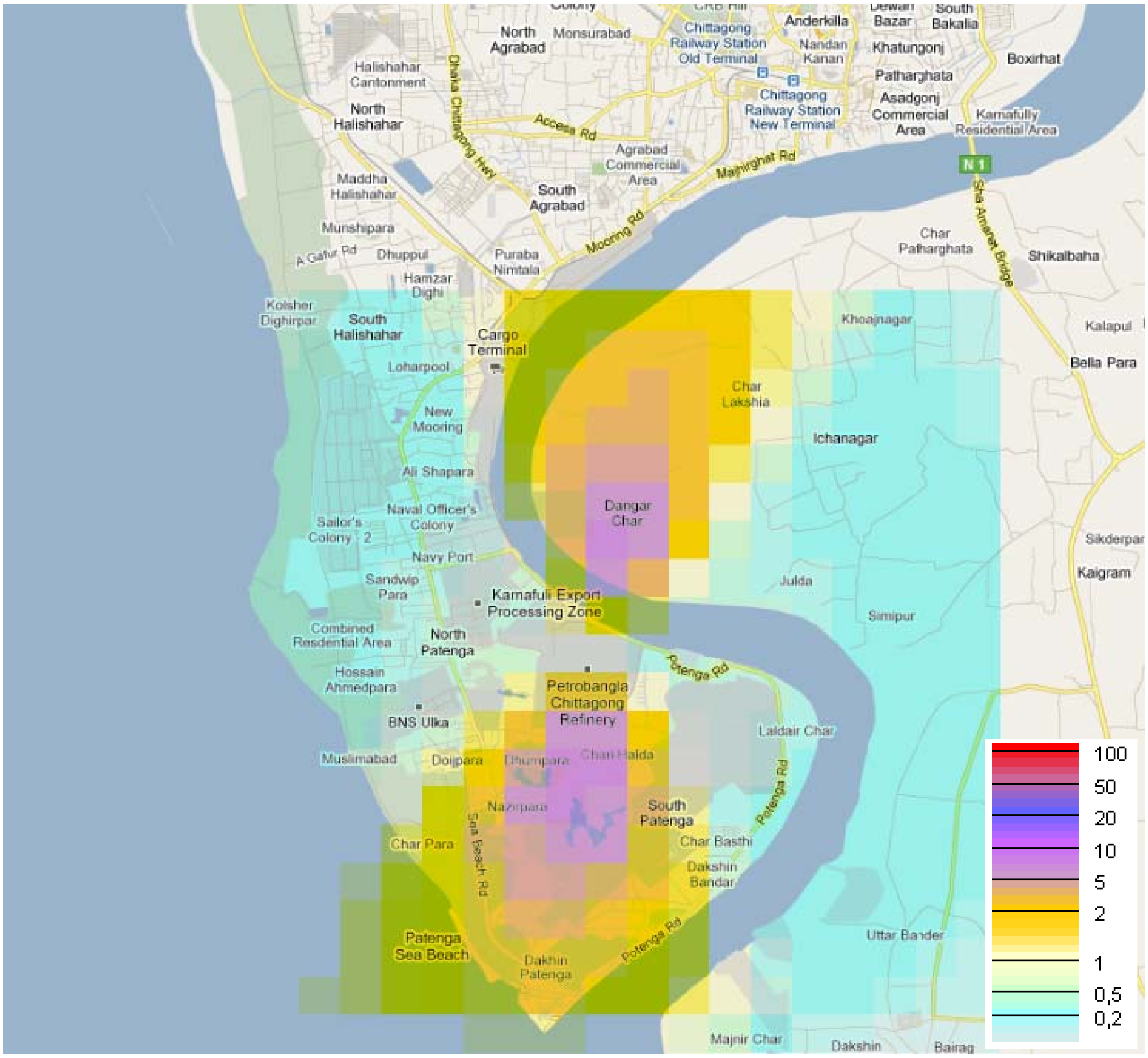
As measurements are not available at ERL, emissions were calculated by assuming typical sulphur concentrations in the various products as per the following table, which shows the approximate total sulphur balance of the refinery.

S Input	**quantity (t/a)**	**S content (%)**	**total S (t/a)**
Murban	520,000	0.72	3,700
Arab light	580,000	1.78	10,300
Gas condensate	160,000	0.01	16
Total			**14,000**

S Output	**Arab light**		**Murban**		**Condensate**		
	% of input	**% S**	**% of input**	**% S**	**% of input**	**% S**	**total S (t/a)**
Vac residue	24,3	4,5	7,3	1,68			6,300
Vac gasoil	20,4	2,5	28,8	1,5			3,100
gasoil	20,3	0,85	26,6	0,7			1,100
kero	9,7	0,16	11,3	0,17			100
naphtha	23,6	0,045	25	0,09	100	0,011	1,900
ref gas	0,2	0,02	0,2	0,018			-
LPG	1,5	0,02	0,8	0,02			-
losses							1,500
Total							**14,000**

Of the total sulphur input approximately 1500 t/a (11 %) are emitted directly by the refinery. The rest is emitted during the use of the products all over the country. The refinery SO_2 emission is not significantly higher than the EU average in 1995 - the relevant deviation is the complete lack of any sulphur recovery in the refinery. From an environmental point of view the focus is not on the relatively small amount of direct SO_2 from the refinery but on the large amount of sulphur that is emitted via the refinery products.

The calculated ground level concentrations are:



SO_2 ground level concentration (GLC)					
compound	**parameter**	**GLC baseline µg/m³**	**GLC refinery µg/m³**	**GLC refinery % of limit**	**GLC relevant limits µg/m³**
SO_2	yearly average	xxx	max. 8	max. 8	EU : 50 BD : 100

The contribution of the refinery to the total SO_2 ground level concentration is significant in two relatively small areas north and south of refinery but not in the densely populated parts of Chittagong. Mitigation measures should focus on installing sulphur reduction processes in the refinery to improve product desulphurisation, this would increase the urban air quality with a significantly higher efficiency.

It has to be taken into consideration that SO_2 from the refinery is emitted from relatively high stacks at high temperatures - both parameters significantly improve the dispersion. Sulphur dioxide from combustion of fossil fuels - especially from motor vehicles - is emitted at very low level. Therefore, sulphur dioxide from motor vehicles is clearly more relevant for the urban air pollution.

1.1.3. NOx

Environmental relevance

Oxides of nitrogen (NOx) when emitted to the air can combine with water and form a cornponent of 'acid rain'. Further NO, in combination with volatile organic compounds and sunlight, can lead to the formation of ground-level ozone. The most relevant source of NOx in general is motor vehicles - especially within cities.

Legal limits for the ambient ground level concentration (air quality standard) are:

Bangladesh 100 µg/m³ (no further specification)[1]

EU 40 µg/m³ (NOx as NO_2 - yearly average)

The actual NOx concentration in the Chittagong area is xxx µ/m³, i.e. the air quality does not comply with international standards.

Refinery sources and best available mitigation technologies

NOx emissions from refineries depend mainly on the fuel type, combustor equipment design, and operating conditions. Accordingly, large differences in the NOx emission level can be expected between refineries and even within different combustion equipment at the same refinery at different times. The influence of temperature is most important with NOx emissions increasing exponentially with combustion temperature.

NOx emissions are also magnified by the use of fuels containing fuel bound nitrogen. The fuel NOx contributions can range from nonexistent, as in the case of natural gas fuelled equipment, to several times the thermal NOx contribution of the equipment for refinery fuels.

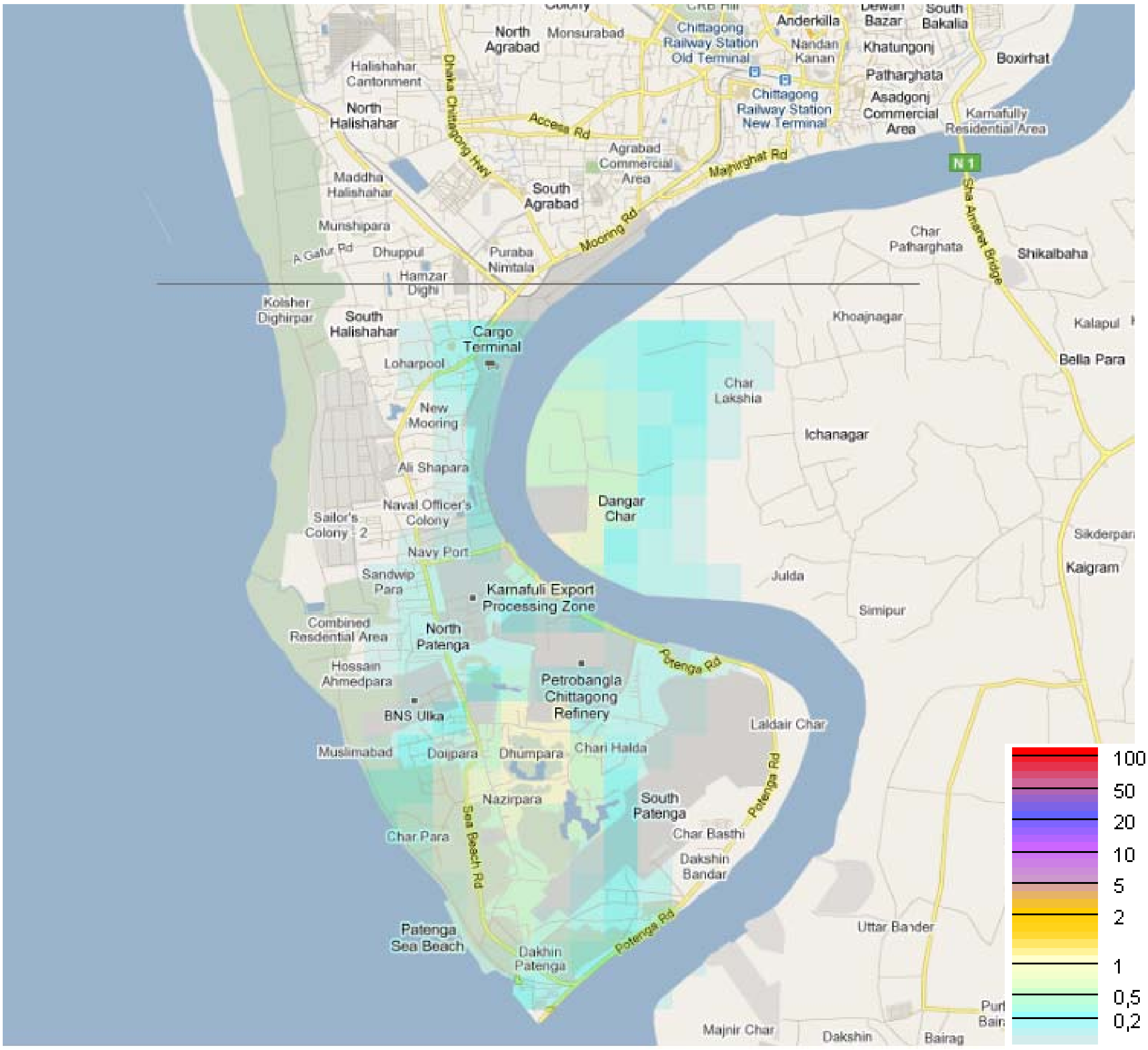
Combustion modifications involve changes to the combustion equipment or operating conditions that either lower the flame temperature or change the concentration of reactants to minimise NOx formation. The most relevant technologies are low NOx burners and flue gas recirculation. Low NOx burners, either air staged or fuel staged, have the aim of reducing peak temperature, reducing oxygen concentration in the primary combustion zone and reducing the residence time at high temperature, thereby decreasing thermally formed NOx. Staging of fuel addition is also thought to provide a reburning effect, further reducing the NOx. The decreases obtained by low NOx burners average around 40%.

Post-combustion techniques include Selective Non-Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR). SNCR and SCR have been used for large boilers and for gas-fired refinery heaters but are not to be considered best available technology for refinery process heaters due to high cost and limited efficiency.

[1] Environment Conservation Act 1995

ERL emissions and ground level concentrations

As measurements are not available at ERL, typical emission concentrations were taken from literature. 250 mg/m³ were assumed for gas fuel, 300 mg/m³ for liquid fuel and 400 mg/m³ for diesel engines. The calculated ground level are shown in the following map.



<table>
<tr><td colspan="6">NOx ground level concentration (GLC)</td></tr>
<tr><td>compound</td><td>parameter</td><td>GLC baseline µg/m³</td><td>GLC refinery µg/m³</td><td>GLC refinery % of limit</td><td>GLC relevant limits µg/m³</td></tr>
<tr><td>NOx (as NO_2)</td><td>yearly average</td><td>approx. 50</td><td>max. 1</td><td>max. 1</td><td>EU : 40
BD : 100</td></tr>
</table>

The refinery does not apply any specific NOx abatement technologies. However, its contribution to the overall NOx air pollution in the relevant neighbourhood is less than 3 % of the air quality standard of 100 µg/m³ and thus can be regarded as not relevant. Mitigation measures regarding the existing installations are not recommended.

1.1.4. VOC

Environmental relevance

Volatile organic compounds (VOC) is the generic term applied to all compounds containing organic carbon, which evaporate at ambient temperature and contribute to the formation of 'summer smog' and odour nuisance. The main source of VOC is motor vehicles mainly from partial combustion in the engine but also from direct evaporation of motor petrol.

Because VOC is always a mixture of very different hydrocarbons including non-toxic components as well as cancerogenics it is very difficult to define reasonable air quality limits. In the EU there are limits for benzene as a relevant component but not for VOC in total. As a rough estimate it is reasonable to assume approximately the same air quality limits as for NOx and SO_2, i.e. 100 µg/m³.

Refinery sources and best available mitigation techniques

Fugitive emissions from process equipment are the largest single source of VOCs emitted to the atmosphere in a refinery and can frequently account for 50% of the total emissions. Fugitive emissions embrace the emissions that occur from items such as valves, pump and compressor seals, flanges, vents and open ends.

Factors driving these releases of hydrocarbons are equipment design, quality of the sealing system, maintenance programme and properties of the line contents. Poorer designs (with wider tolerances), poor sealing systems (e.g. leak prone valve packings) and limited maintenance will lead to higher emissions. Valves are considered to account for approximately 50-60% of fugitive emissions. Furthermore, the major portion of fugitive emissions comes from only a small fraction of the sources (e.g. less than 1% of valves in gas/vapour service can account for over 70% of the fugitive emissions of a refinery).

There are numerous techniques to minimise VOC emissions - not all of them are applicable in a retrofit situation.

- Leak Detection and Repair (LDAR) Programmes: The main experience of LDAR programmes has been in the USA where since the early 1980s. The technique for LDAR is to measure the concentration of gas at the potential leak site on the piping component (under a prescribed procedure) and to effect a repair to the leaking item if a level of gas concentration equal to or greater than a regulatory leak definition concentration (10 000 ppm) is measured. Over 90% of reducible fugitive VOC emissions originate from only approx. 0.1% of components.
- VOC collection or balancing systems for storage and loading of highly volatile products.
- Rim seals with a higher efficiency for floating roof tanks.
- Covering wastewater separators.
- VOC collection systems in process units: VOC from vents, pumps and compressors can be collected and routed to a flare system.
- selection of valves with intrinsically low fugitive emissions either by manufacturer type and/or packing.

- Pumps and compressors fitted with improved seals and sealing liquids.
- Providing pumps with sumps and drains connected to a closed system for the collection of spills.
- Using closed-loop sampling systems and collection systems, with segregation of wet and dry oil waste streams.
- Routing of offgases to nearby heaters/incinerators/flares for destruction as appropriate.

ERL emissions and ground level concentrations

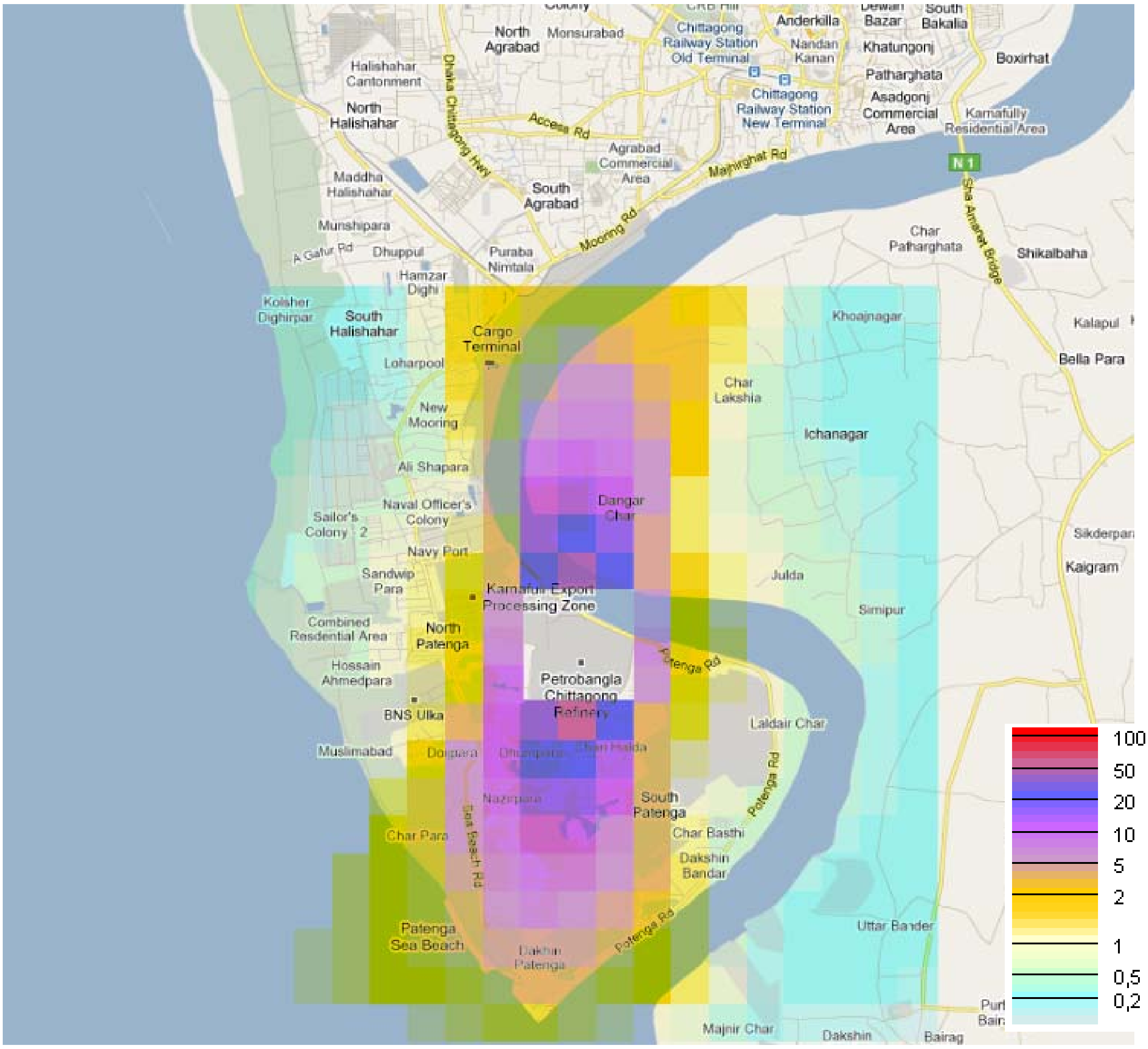
To assess the VOC emission from the ERL refinery the following assumptions were made:

Storage: The emissions of the crude tanks were calculated by applying the programme TANKS of the US EPA based on the actual crude import and tank dimensions. It was then assumed that the emission from product storage would be in the same order of magnitude.

API separator: The emissions were estimated based on the total surface of the existing separator and an emission factor of 20 g/m²h for existing installations [BREF]. The emission rate was doubled to take the additional emissions of the large sludge basin into consideration.

Fugitive emissions from gaskets: An emission factor of 0,05 kg/t was assumed [BREF].

The calculated ground level concentrations are:



VOC ground level concentration (GLC)					
compound	**parameter**	**GLC baseline µg/m³**	**GLC refinery µg/m³**	**GLC refinery % of limit**	**GLC relevant limits µg/m³**
VOC	yearly average	xxx	max. 50	max. 50	(100)

The contribution of the refinery to the total VOC ground level concentration is significant in the southern part of Chittagong. Mitigation measures should be taken.

Findings:

- An emission inventory as the basis for a systematic process of improvement is not in place.
- SO_2: There are no specific emission reduction techniques in place, the refinery does not even have any relevant product desulphurisation. Direct SO_2 contribute significantly to the overall SO_2 pollution in some neighbouring areas, however not in the total Chittagong area. The SO_2 pollution in the city is governed by the sulphur content in the liquid fuels; desulphurisation of products is more important than the reduction of direct emissions at the refinery.
- NOx: There are no emission reduction techniques in place. Because the refinery does not contribute significantly to the overall NOx pollution, emission reduction for the existing installations is not an issue of first priority.
- VOC: There are no emission reduction techniques in place. The refinery is a relevant VOC polluter in the southern Chittagong area. Contrary to NOx and SO_2 VOC emission come from a large number of very different sources. Mitigation measures should be taken based on a systematic and detailed emission inventory.

1.2. Water management and wastewater

Water is used intensively in a refinery as process water and for cooling purposes. Its use contaminates the water with hydrocarbons mainly increasing the oxygen demand of the effluent.

Process water has been in direct contact with the process media, and apart from oil, will also have taken up hydrogen sulphide (H_2S), ammonia (NH_3), phenols and others. There more severe the conversion processes, the more H_2S and NH_3 are taken up by the process water. Process wastewater is normally treated in several steps before discharge to the environment.

Cooling water - either once-through or circulating - does not get into contact with process media during normal operation. It can be contaminated in case of leakage of a heat exchanger.

Contaminated surface water comes from rainfall on surfaces that are oil-contaminated such as process areas, pump stations etc. and normally is treated together with the process water.

Uncontaminated surface water comes from areas that are not contaminated and is normally discharged without treatment together with the cooling water.

1.2.1. Best available technology in refinery wastewater treatment

Best available technology of refinery wastewater treatment is a three stage treatment.

Primary treatment facilities are separators, which provide an environment in which suspended solids can be settled coincidentally with the separation of oil in the influent. They are facilities, which will separate free oil from waste water but will not separate soluble substances, nor will they break emulsions. Despite their relative simplicity, most of the oil in the effluent will be recovered at the primary treatment stage and is recycled to the process units. A pre-separator (pre-sedimentation basin or sludge trap) may be provided upstream of a gravity separator where heavily polluted influent streams are present, its primary function being to allow the removal of gross oil and settling of solids which would otherwise impair the performance of the downstream separator basin.

An API separator is the simplest form of separator, the separating chamber simply consisting of an open rectangular basin. The standard API separators existing in many refineries comprise an inlet section and oil-water separation chambers. The approach channel and transition part are usually constructed in at least two bays in order to facilitate their cleaning and repair when required. Flight scrapers may be installed to gently move the sludge to a sludge collection pit and oil to the oil skimming device. Covers may be installed to reduce odour and emissions to the air of Volatile Organic Compounds (VOC).

The main advantage of the API separator is that its large volume can intercept large slugs of free oil and solids. This factor helps to improve the performance of the downstream stages. Its main disadvantages are that it requires a large area of land and can only remove comparatively large oil droplets.

Secondary treatment is aiming at reducing emulsified contaminants. Flotation devices are forms of enhanced gravity separation which rely on the formation of weak bonds between air bubbles and oil and solid particles. The air bubbles provide the necessary buoyancy to float the oil and solid particles to the water surface for skimming. Flotation units are capable of separating and removing virtually all free oil from an effluent stream and can significantly reduce the concentration of suspended solids, but as with normal gravity separators, they will not separate out soluble substances. An added benefit of air operated flotation units is that they increase the dissolved oxygen content of the effluent.

Tertiary treatment is a biological treatment of effluent water based on the process in which a mixed population of micro-organisms use as nutrients substances that contaminate the water. This is the same mechanism by which healthy natural waterways, such as rivers and lakes, purify themselves. This basic process has been intensified and accelerated to give a wide range of treatment plant systems for treating refinery effluent water. Effluent water containing polluting material is brought into contact with a dense population of suitable micro-organisms for a time sufficient for the microbes to break down the contaminants. The pollutants are adsorbed into the microbial mass, typically oxidised, and partly converted into new cell material.

Aerobic processes remove a wide range of carbonaceous material, typically characterised in terms of the associated oxygen demand (e.g. TOD/COD/BOD or TOC) and individual compounds such as phenols, ammonia and sulphide. Anoxic treatment can also reduce levels of Total Nitrogen.

1.2.2. Eastern Refinery

Raw water (approx. 150 m³/h) is pumped from wells at the site and used for

- cooling (direct cooling and make-up of cooling water cycles) - approx. 90 m³/h
- boiler feed water - approx. 15 m³/h
- process water - approx. 45 m³/h

The total wastewater flow is approx. 50 m³/h. This is equivalent to approx. 300 l/t of crude. The specific wastewater quantities of six German refineries are reported to be between 100 and 300 l/t with an average of 200 l/t. Taking into account that the wastewater quantity increases with the complexity of the refinery, there is significant potential of improvement for the Eastern refinery regarding the mere quantity of wastewater.

The wastewater is treated only by an API separator, i.e. there is no secondary or tertiary treatment at all.

Concentrations for some of the most relevant contaminants in the treated wastewater were available (see following table).

Effluent parameters (after primary treatment)				
Parameter		**ER test results**	**EU BREF**	**Bangladesh standard***
BOD_5	mg/l	28	150 - 400	30
COD	mg/l	165	300 - 700	(200)
total solids	mg/l	1593	-	(2100)
suspended solids		no data	20 - 75	(150)
oil and grease	mg/l	6.6	40 - 100	10
sulphide	mg/l	no data	5 - 15	1
total N	mg/l	no data	25 - 50	(100)
phenols	mg/l	no data	12 - 40	1
phosphate	mg/l	no data	5 - 20	(8)
benzene + BTX	mg/l	no data	4 - 15	-
heavy metals	mg/l	no data	1 -2	-

* ENVIRONMENT CONSERVATION ACT 1995 ACT 1 OF 1995, Schedule 12 K: according to rule 12 only the parameters in Schedule 12 K are applicable to refineries - not the parameters given in Schedule 10 (for not dedicated industries), the latter are given here in brackets.

Findings

- The concentration data as given by the refinery do not match with the general state of knowledge regarding the efficiency of primary treatment of refinery wastewater. The data are highly questionable and the analyses should be carefully repeated.
- Based on international data on the efficiency of primary treatment facilities, the wastewater quality does not comply with international standards or with Bangladesh legal requirements. The existing legal requirements cannot be complied with by applying only primary treatment. Improvement of the existing wastewater treatment should be considered with high priority.

1.3. Waste management

According to EU-BREF refineries produce up to 2 kg/t of solid waste and sludge related to the quantity of processed crude. This total quantity can be split into

- 45 % sludge mainly from wastewater treatment and tanks
- 20 % other refinery wastes - mainly spent catalysts (FCC units) and absorbents
- 35 % non-refinery waste mainly domestic waste, scrap metal, package material

Of this waste approximately 80 % is considered hazardous due to its content of hydrocarbons and heavy metals and has to be disposed according to special requirements and in special installations.

The waste was disposed in the following ways:

- 40 % landfill (absorbents, catalysts, non-refinery waste)
- 20 % recycled or reused (sludge, non-refinery waste, catalysts)
- 25 % dedicated waste incineration facilities (sludge)
- 2 % alternative fuel (sludge)

The situation for the Eastern Refinery is completely different:

Oily sludge mainly from the API separators are the most relevant source of waste at the Eastern refinery. The total sludge produced is approx. 4000 bbl, approx. 650 t/a or 0,43 kg/t. Compared to more complex refineries, the total quantity of waste is significantly lower as there are less spent catalysts and absorbents that have to be disposed and there is no sludge from secondary or tertiary wastewater treatment. The comparatively low figure of 0,43 kg/t is simply due to the low complexity and low standard of wastewater treatment and does not mean that there is an effective waste management in place.

The sludge is stored at an open pit and then sold as alternative fuel, i.e. the sludge is not considered as waste that has to be managed under special control but as some kind of additional product.

Apart from the emissions to the air from this area and the risk of soil contamination it has to be considered, that this approach is only possible because the legal framework in Bangladesh still does not comply with international standards.

Future constraints could come directly from legal requirements but also from offtakers, who might run into problems with their combustion facilities that could have to cope with increasingly strict air emission control requirements.

Today, waste production in refineries represents a high contribution to the operating cost and potential environmental risk, and as such its minimisation should be a priority.

Findings

- At the time being the sludge is handled as a product and not managed as a hazardous waste. Future restrictions that will terminate or complicate the use as marketable alternative fuel must be expected and will impose a relevant additional cost aspect to the refinery operation. Alternative solutions have to be identified.
- The existing sludge handling in an open pit causes additional environmental problem such as air pollution or soil contamination.

1.4. Safety

1.4.1. Process safety management

Refineries have caused numerous accidents all over the world. This is mainly due to the fact that highly flammable substances and also toxic substances (H_2S) are used at large quantities, high pressures and temperatures.

Refinery fire

Light hydrocarbons are classified as highly or extremely flammable, in case of major releases heavy gas clouds are formed that can travel considerable distances before being ignited. On ignition, the fire will flash back to the originating equipment and will cause further equipment to fail. Further explosion a fast increase of the fire can occur.

In response to a number of serious accidents that occurred in the 1970s and 1980s, process safety management regulations were developed especially in the EU and the United States. In the EU it is the so-called Seveso II guideline that covers thousands of industrial installations handling hazardous substances including all refineries.

The main elements and basic requirements of the process safety management systems according to Seveso II are:

I Organization and personnel	▪ Roles and responsibilities of personnel involved in the management of major hazards at all levels in organization have to be defined clearly and in writing;

II	**Identification and evaluation of hazards**	▪ Adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation and the assessment of their likelihood and severity - i.e. formalised process hazard analysis methods such as HAZOP for all safety relevant units;
III	**Operational control**	▪ Adoption and implementation of procedures and instructions for safe operation including inspection and maintenance, of plant, processes, equipment and temporary stoppages;
IV	**Management of change**	▪ Adoption and implementation of procedures for planning modifications to, or the design of new installations, processes and storage facilities;
V	**Planning for emergencies**	▪ Adoption and implementation of procedures to identify forseeable emergencies by systematic analysis -e.g. consequence calculations for explosions, fires and release of toxic substances and identification of safety distances; ▪ Adoption and implementation of procedures to prepare, test and review emergency plans to respond to such emergencies;
VI	**Monitoring performance**	▪ Adoption and implementation of procedures for the ongoing assessment of compliance with the objectives set by the operator´s major accident protection policy and safety management system, and the mechanisms for investigation and taking corrective action in case of non-compliance; ▪ The procedure should cover the the operator´s system for reporting major accidents or near misses, particularly those involving failure of protective measures, and their investigation and follow-up on the basis of lessons learnt;
VII	**Audit and review**	▪ Adoption and implementation of procedures for periodic and systematic assessment of the major-accident prevention policy and the effectiveness and suitability of the safety management system and its updating by senior management;

It is not within the scope of this study to go for an in-depth study of the individual elements of process safety management. Although a formalised safety management system is not a legal requirement in Bangladesh, the Eastern Refinery has a safety management systems according to the companies policy.

1.4.2. Safety distances

To cope with consequences of major accidents it is international best practice to keep certain safety distances between a tank farm and the neighbouring housing areas. Such safety distances are either based on standards or on consequence calculations.

Safety distances for land use planning of areas with hazardous industrial installations according to the EU Seveso Directive are legal guidelines for land use planning processes dealing with new installations. They are based on consequence calculations and on the evaluation of actual incidents. They do not reflect existing situations which in many cases do not comply with these requirements, i.e. when these distances are not given the situation should be studied in more detail. On the other hand, if these distances are given, a relevant risk can generally be ruled out. For refineries that do not handled relevant quantities of toxic substances like H_2S such planning safety distances are in the range of 200 m depending on the individual country.

NFPA 30 by the US National Fire Protection Association is a fire safety standard for installations handling flammable liquids and requires safety distances depending on process conditions, vessel type and available safety equipment. The required distance for refinery process equipment that is comparable to Eastern Refinery is 200 m.

Eastern Refinery with 200 m safety distance line to the west and south

As can easily be seen from the aerial photo of the southern and western part of the Eastern Refinery some housing areas are located within the 200 m safety distance. This does not mean that such distances are not acceptable at all, as a minimum requirement the consequences based on realistic scenarios have to be assessed and measures taken - such as integrating these housing areas into an emergency response plan. Future extension of the refinery here would be critical.

Of all media stored at a refinery LPG is the most critical due to its high tendency of forming heavy gas clouds. The two existing aboveground spheres do not comply with international best practice (no automatic overfilling protection, no protection against underfiring and BLEVE), however, the distance to the next housing area is more than 500 m and thus not critical.

1.4.3. Process hazard analyses

Formalised and systematic process hazards analyses (HAZOP) belong to the most important elements of process safety management. HAZOP to be kept as-built or a formal classification of dedicated safety integrated functions (SIL - safety integrity levels) is not available.

Findings:

- A safety distance of 200 m to housing areas according to EU and US standards is not available. This deficiency should be studied in more detail and measures such as special emergency management and response plans should be considered.
- The existing elements of the existing safety management system should be reviewed against international standards such as the EU Seveso II guideline.
- A plan should be set up to perform HAZOP studies at least for the most relevant relevant process units.

2. Marketing

2.1. Indirect environmental impacts of the hydrocarbon sector

This study is not aiming at the environmental impacts of the use of hydrocarbons, i.e. the indirect impacts of the hydrocarbon sector. However, it has to be kept in mind, that these indirect emissions are significantly more relevant for the overall environmental situation in Bangladesh than the direct impacts from refining and marketing of hydrocarbon fuels. Political decision making regarding liquid fuels has always been strongly influenced by such indirect environmental aspects and for this reason at least a general outline of these indirect impact will be given.

Air pollution is an important public health problem in most cities of the developing world. Epidemiological studies show that air pollution in developing countries accounts for many excess deaths and billions of dollars in medical costs and loss of productivity every year. These losses and the associated degradation in quality of life impose a significant burden on people in all sectors of society. Common air pollutants in urban cities in developing countries include:

- Respirable particulate matter from smoky diesel verhicles, two stroke motorcycles and 3-wheelers, burning of waste and firewood, entrained road dust and stationary industrial sources
- Carbon monoxide from gasoline vehicles and burning of waste and firewood
- Photochemical smog (ozone) produced by the reaction of volatile organic compounds (VOC) and nitrogen oxides in the presence of sunlight; motor vehicle emissions are a major source of nitrogen oxides and VOC
- Sulphur oxides from combustion of sulphur-containing fuels and industrial processes
- Secondary particulate matter formed in the atmosphere by reactions involving ozone, sulphur, nitrogen oxides and VOC

- Known or suspected carcinogens such as benzene, 1,3-butadiene or polynuclear aromatics mainly from motor vehicle exhaust.

It is obvious that the use of liquid hydrocarbons as fuel for in motor vehicles is the main source of most of these contaminants. Thus, hydrocarbon marketing policy is also environmental policy.

There is no detailed emission inventory for vehicular pollution in Bangladesh. World Bank studies show very high concentrations of particulate matter (PM_{10} and $PM_{2.5}$) in Dhaka along with other big cities of this sub-continent. It is evident from the data that current concentration of ambient particulate concentration is much higher than the national permissible level and WHO standards. This deterioration in the ambient concentration of particulate matters to a great extent can be attributed to motor vehicles. As there are no big power stations, significant industrial sources of emissions, or deserts to cause dust pollution in cities like Dhaka and Chittagong, it can be said that motor vehicles are the main source of the existing pollution.

To mitigate this situation, government had initiated projects like Dhaka Urban Transport Project (DUTP), Air Quality Management Project (AQMP), and Dhaka Clean Fuel Project. The government phased out 2-stroke-3 wheelers from the city with effect from January 2003.

The most viable and abundantly available automobile alternative fuel in Bangladesh is the introduction of CNG as a motor fuel. CNG is a success story for Bangladesh and significantly improved the air quality in the country's urban cities.

After the phase out of 2-stroke-3-wheelers and the introduction of CNG as an alternative fuel, particulate emission from the diesel vehicles is the pollutant of concern.

Unfortunately the gains of phasing out of 2-stroke-e-wheelers and the replacement of petrol by CNG are being progressively lost due to the further increase of low quality diesel vehicles. The main concern in the big cities of Bangladesh today is particulate emissions from diesel engines.

Typical emission factors for the three different fuel types are shown in the following table:

	consumption in g/km	**emissions in g/km**			
	fuel	**VOC**	**PM**	**NOx**	**SO_2**
petrol car EURO-2 [1]	50	0,10	< 0,01	0,18	0,05
petrol car pre-EURO	80	3	0,03	1,7	0,05
diesel car EURO-2 [1]	50	0,08	0,08	0,60	0,15
diesel car pre-EURO	60	0,2	0,2	0,7	0,15
CNG [2]	60	0,03	< 0,01	0,12	< 0,01

[1] UK NAEI National Atmospheric Emissions Inventory VEHICLE EMISSION FACTOR DATABASE 2003, sulphur 500 ppm for petrol and 2500 ppm for diesel

[2] LANUV, Landesamt für Naturschutz, Umweltschutz, Verbraucherschutz, Essen, Germany

The comparison clearly shows that CNG has significant advantages over diesel as a fuel for mobile vehicles especially regarding particulate emissions and sulphur. The use of CNG for motor vehicles is a relevant contribution to air quality in urban cities of Bangladesh and explicitly part of the environmental policy of the government.

Most mitigation measures to reduce vehicle emissions are aiming at technical improvements at the vehicles themselves. However, to a significant extent possible measures are also product related and have to be considered within the scope of this study.

Du to the importance of diesel for the urban air quality diesel product quality is a relevant issue. The current level of sulfur content in diesel is 2500 ppm. The current EU standard is 10 ppm. There seems to be no immediate plan to reduce diesel sulfur to 500 ppm because of the cost implications. Apart from that the Eastern Refinery has no desulphurization capacity at all. Reducing the sulphur content in diesel is also an infrastructural problem.

Not only sulphur emissions can be mitigated by product related measures. Diesel particulate emissions can also be influenced by the product quality of diesel, e.g. by CETAN number and by applying additives.

Any changes in the split between the different fuel in the market will have impact on the air quality. This study is aiming at giving a picture of the future development of the national liquid fuel market. To assess the environmental impacts of such developments the total emissions from the use of liquid hydrocarbons in the market are estimated based on the emission factors given in the table above.

To be on the conservative side, the emission factors for pre-EURO cars have been taken, deviating emission factors for different types of vehicles were neglected - this is acceptable for this estimate because the emission factors were related to the fuel mass; a truck has a higher emission factor per km but also a higher consumption, i.e. the consumption related emission factor does not differ that much. About one third of the total diesel is used in stationary motors for irrigation purposes; the same emission factors were used for this sector also.

	consumption t/a	**total emission in t/a**			
		VOC	**PM**	**NOx**	**SO_2**
petrol	200.000	7500	75	4300	130
diesel	2.300.000	7700	7700	26800	5800

This estimate figures will be used later to evaluate the air quality impact of the increasing demand and possible shifts in consumption between different fuels.

2.2. Direct emissions of the marketing installations to the atmosphere

The environmental impacts of the marketing installations originate from storage and distribution facilities, i.e. mainly depots and petrol filling stations.

Marketing installations comprise

- approx. 70 depots

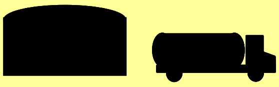
- approx. 1500 petrol stations

Because there are no other activities besides storage and loading/unloading emissions are related to evaporative losses during these operations.

Emission inventories of individual installations or for all depots and petrol stations are not available. There are no emission relevant differences between the individual depots and petrol stations - the only difference is the storage capacity and throughput.

To achieve a set of data that can be handled within the scope of this study emission factors were calculated for a standard or average depot.

The only product with relevant air emissions is petrol or motor spirit. Diesel has not ubstantial vapour pressure and its emissions can be neglected. The emission of a tank can be split into standing losses - due to breathing of the tank because of day/night temperature differences - and working losses - due to displacement of petrol saturated air during filling of a tank.



total sales - motor spirit incl. blending components	200 000 t/a
vapour pressure (RVP) (Singapore Property Standard: max 10)	8
depot throughput typical	3 000 t/a
number of tanks typical	1 (fixed roof)
tank volume	1 000 m³
calculation results according to EPA TANKS	
working losses tank filling	4 500 kg/a
standing losses	23 000 kg/a
working losses truck filling	4 500 kg/a
total tank losses	32 000 kg/a

The working losses are calculated for the tank only.
Additional working losses in the same order of magnitude
are caused by the filling of tank trucks.

depot emission factor (losses per throughput)	**10.6 kg/t**
total emission of all depots	**2 100 t/a**

The emissions of petrol station comprise mainly of working losses caused by the filling of the stationary tank and the filling of the vehicle tank.

petrol station losses (2 times depot working losses, no standing losses)

petrol station emission factor	**3.0 kg/t**
total emission	**600 t/a**

The emissions from storage and handling were calculated for the typical 3000 t/a depot. These calculated emissions were related to the actual petrol throughput, the resulting emission factor can be used to estimated the emissions of all depots.

The emission factor for petrol station can be approximated as twice the working losses - filling the stationary tank at the petrol station and filling vehicle tank.

As a result the figures show the the VOC emission of the supply chain (2 700 t/a) are significantly less than the VOC emission of the consumption (15 200 t/a) - however it cannot be neglected.

There are no reduction technologies applied at the depots and at the petrol stations.

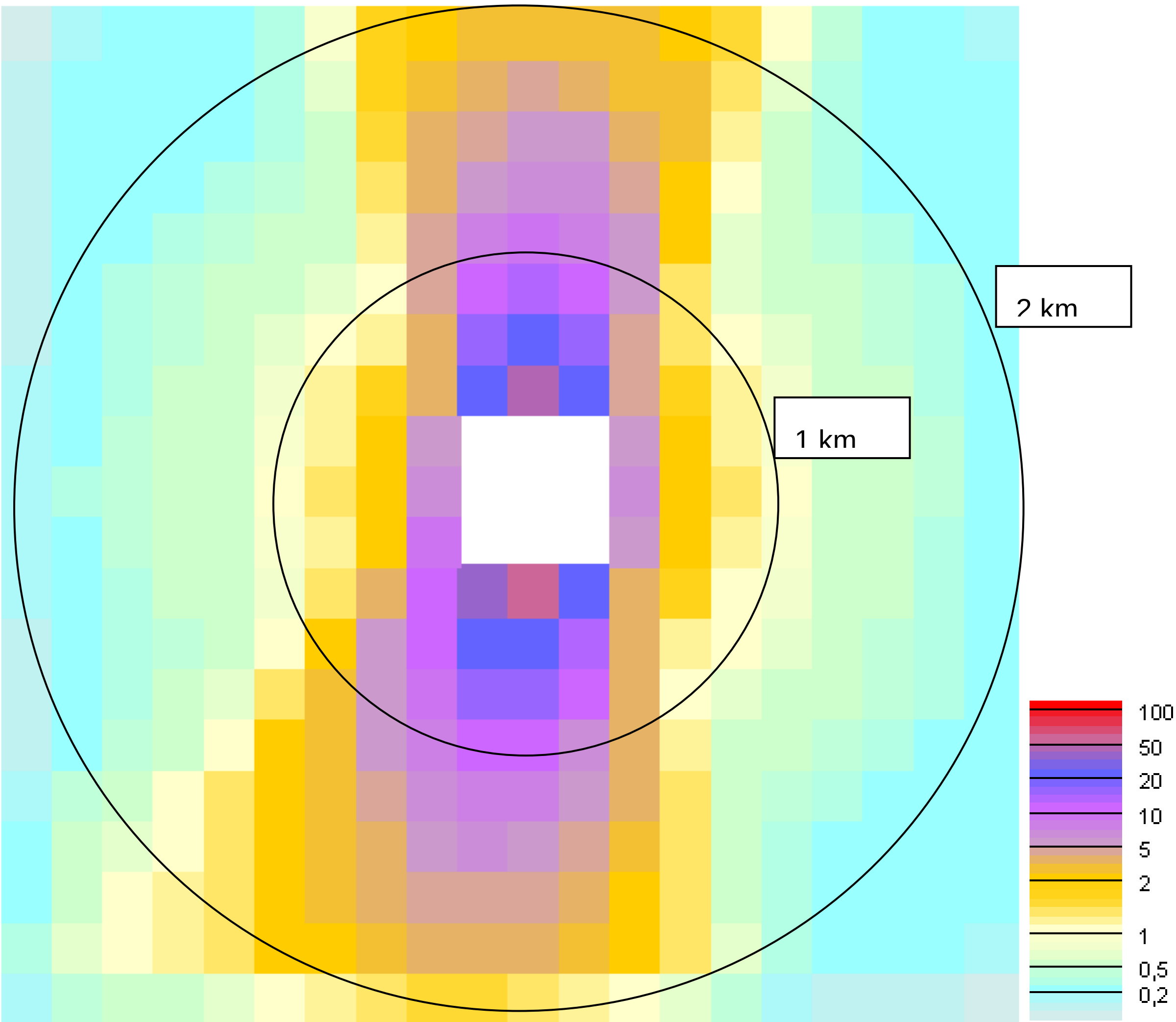
Possible mitigation measures for tank farms are:

- Breathing valves at the tank vents with appropriate setting pressures will reduce standing losses due to breathing to a certain extent. The set points are related to the design pressure of the tanks, i.e. for existing tanks the efficiency of tis measure is limited.
- The displaced vapour phase from the tank that is being filled can be routed back to the tank that is being emptied via a balancing line. Trucks are usually filled from open man holes at the top - the collection of the displaced vapour is not possible without significant changes to the loading equipment.
- Surplus vapour phase that cannot be balanced can be recovered by adsorption or absorption or incinerated.

At petrol stations gas balancing is difficult to apply because the connection between the car tank and the filling nozzle is not gas-tight. In Europe petrol stations are equipped with active gas balancing systems, i.e. the vapour is sucked back to the tank of the petrol station by special pumps.

Apart from the overall relevance of the supply chain emissions the local impact, i.e. the contribution of a depot to the local air pollution is another aspect.

The calculated ground level concentrations for the typical 3000 t/a deport are shown in the following figure.



VOC ground level concentration (GLC)					
compound	**parameter**	**GLC baseline µg/m³**	**GLC depot µg/m³**	**GLC depot % of limit**	**GLC relevant limits µg/m³**
VOC	yearly average	xxx	max. 20	20	(100)

Findings:

- The contribution of a typical depot to the total VOC ground level concentration is significant within a distance of approx. 1 km from the depot. Mitigation measures should be considered at least for major depots in densely populated areas.
- The air quality impact of liquid hydrocarbons has to attributed to the use of the products, the direct emissions of the marketing installations are less relevant. Political or marketing measures that could change the existing split of products between diesel, petrol and CNG can have relevant environmental effects that have to be taken into account.
- Emissions from mobile or stationary diesel engines strongly depend on the engine technology but to some extend on the product quality also especially regarding sulphur and particulate emissions. Existing diesel specifications should be reviewed under this aspect.

2.3. Emissions to water

Depots and petrol stations do not produce process related wastewater in significant quantities.

2.4. Waste generation

Depots and petrol stations do not produce process related waste in significant quantities.

2.5. Accidental contamination of soil, groundwater and surface water

Filling operations of tank trucks, ships and drums can always cause accidental contamination of soil, groundwater or surface water.

Filling of drums at a depot

According to the international best practice filling of mobile equipment at storage facilities and also at petrol stations is performed at dedicated places, which are protected by bunding and surfaces resistant to mineral oils.

At the depots and petrol stations no specific no measures of that kind could be observed.

The storage tanks are located within a bunding - there are some doubts regarding the qualification of the existing bunding in terms of volume and quality - later changes to the original bunding could have reduced the available retention capacity.

Storage tank at depot with „access gap“ in bunding

***Findings**:*

- The existing installations and practices should be reviewed against international standards and an improvement plan should be set up based on the individual risk and the required expenditure.

2.6. Safety

Depot tank fire

Compared to other types of industrial facilities, tank farms with inflammable liquids cause numerous accidents all over the world. This is mainly due to the fact that filling operations usually imply manual action which is always prone to operational failures.

Petrol is a highly flammable liquid, in case of major releases heavy gas clouds are formed that can travel considerable distances before being ignited. On ignition, the fire will flash back to the originating tank and result in tank fire.

Group of tanks on fire with secondary fire in the neighbourhood

The explosion and the resulting tank fire can cause severe damage to the adjacent tanks and to the neighbourhood of the tank farm. With one tank fully on fire neighbouring tanks could ignite also and further explosions can occur. Tanks on fire can “boil over” by sudden evaporation of water at the bottom of the tank. Such secondary effects can cause extreme hazards to emergency staff and people close to the tank.

Although diesel is not highly flammable but only flammable diesel tanks can be set on fire by the heat radition from a neighbouring petrol tank. Tanks on fire can “boil over” by sudden evaporation of water at the bottom of the tank. Such secondary effects can cause extreme hazards to emergency staff and people close to the tank.

2.6.1. Safety distances

To cope with such consequences it is international best practice to keep certain safety distances between a tank farm and the neighbouring housing areas.

Safety distances for land use planning of areas with hazardous industrial installations according to the EU Seveso Directive are legal guidelines for land use planning processes dealing with new installations. They are based on consequence calculations and on the evaluation of actual incidents. They do not reflect existing situations which in many cases do not comply with these requirements, i.e. when these distances are not given the situation should be studied in more detail. On the other hand, if these distances are given, a relevant risk can generally be ruled out. For tank farms such planning safety distances are in the range of 200 m depending on the individual country.

NFPA 30 by the US National Fire Protection Association is a fire safety standard for installations handling flammable liquids and requires safety distances depending on tank volume, tank type and available safety equipment. The required distance is 52 m for tanks larger than 380 m^3 and 66 m for tanks larger than 2000 m^3.

As can easily be seen from the following figure from a Dhaka depot the actual distances are significantly smaller - in this case less than 20 m. Smaller safety distances are possible according to some standards, if specified safety measures are in place. However, this is not the case here.

Safety distances seem to be a general problem for the existing depots.

Existing safety distances at Dhaka depot

2.6.2. Fire fighting

The depots visited are equipped with some fire fighting equipment, however, it was quite obvious that the existing installation does not comply with standards such as NFPA 30. The fire fighting pumps and mains have not been used for very long times and mock drills are not performed on a regular basis according to standards.

2.6.3. Safety management

Some elements of a safety management systems seem to be in place according to the Explosion Protection Law. However, there are no third-party audits on a regular basis and no formalised improvement process.

Findings:

- A safety distance according to EU and US standards is not available at least for some depots. This deficiency should be studied in more detail and measures such as special emergency management and response plans should be considered.
- The elements of the existing safety management system should be reviewed against international standards such as the EU Seveso II guideline taking into account the relatively simple nature of depots processes.
- Fire fighting should be reviewed against relevant standards. Regular mock drills should be performed and documented.