Bangladesh

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Strengthening of the Hydrocarbon Unit in the Energy and Mineral Resources Division (Phase II)

Petroleum Refining & Marketing (Package # 06)

➥ HSE recommendation report

SOFRECO

in association with

srgb

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Abbreviations

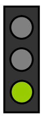
API	American Petroleum Institute
AS	Activated Sludge
BAT	Best Available Techniques
CCR	Catalyst Regeneration Reformer
CDM	Clean Development Mechanism
CDU	Crude Distillation Unit
CPI	Corrugated Plate Interceptor
DAF	Dissolved Air Flotation
EEA	European Environmental Agency
ERL	Eastern Refinery Limited
FCC	Fluid Catalytic Cracking
HAP	Hazardous Air Pollutants
HAZOP	Hazard Operational Analysis
IAF	Induced Air Flotation
LDAR	Leak Detection and Repair
PPI	Parallel Plate Interceptor
SCOT	Shell Claus Off-gas Treating
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SO2	Sulfur dioxide
SRU	Sulphur Recovery Unit
US EPA	U.S. Environmental Protection Agency
VDU	Vacuum Distillation Unit
VOC	Volatile Organic Compound
VRU	Vapour recovery units

1. HSE issues for the refinery

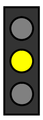
The five technical recommendation scenarios for the refinery have different environmental impacts. In the following report, the environmental impacts of these scenarios are assessed and documented in a comprehensive way.

The base case Scenario 1 is more or less the existing situation including the impacts of increased imports. The relevant emissions for this case of the refinery including the handling of purchased products are given in table 1. The table is mostly the same as for the existing situation (see Assessment Report), however, to facilitate comparison between the five scenarios the emissions of the Chittagong tankfarms that do not belong to the refinery were added. This approach makes sense because for the environmental impacts the actual ownership structure of the refinery and the adjacent tankfarms is irrelevant.

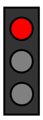
For all scenarios the relevant environmental and safety impacts are listed in an assessment tables per each scenario. For easy comparison and evaluation the individual impacts are ranked by means of red, yellow and green traffic light symbols:



Green: No relevant negative impact, measures applied are according to international standards



Yellow: Impact still acceptable, situation has to be followed-up carefully, mitigation should be considered based on more detailed information during the implementation phase



Red: Relevant negative impact, violation of local requirements or of World Bank requirements, funding by World Bank and similar institutions is questionable, mitigation is required during the implementation phase

1.1 Scenario 1: Current ERL configuration (1.3 MM t/y) and purchase of refined products

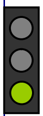
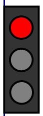
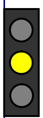
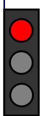
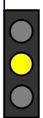
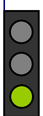
This scenario is considered as base case - the air emissions are given in the following table. The assumptions, on which the figures in the table are based, are described in the Assessment Report.

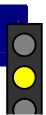
The emissions of light products handling are calculated with an emission factor of 6 kg/t for the year 2010. Heavier products do not contribute significantly to the overall air emissions and can be neglected for this assessment.

Table 1: Air emissions inventory ERL+tankfarms - base case

Tag #	Type	Unit	Fuel	Thermal capacity MW	Flue gas m³/h	Emission concentration mg/m³		Emission flow rate kg/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 pretreatmen t	ref gas	0,97	970	250		0,24	0,39	
F-1202	furnace	cat ref pretreatmen t	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		
	incinera tor	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 generat or	utilities	diesel	7,00	7.000	400		2,80		
	API separat or	utilities								20
	crude storage	tank farm								20
	light product s storage	tank farm loading								220

	diffuse emissions	refinery								60
	total							26	176	325

Parameter air emissions	Quantity	Quantity per capacity	Impact	
NOx	30 kg/h	0,18 kg/t	NOx is emitted from incineration processes such as furnaces, boilers and engines. The refinery does not apply any specific NOx abatement technologies. Due to the low complexity of the refinery the overall furnace capacity is low related to more complex refineries. Although dedicated lownox burners are not applied, the contribution to the overall NOx air pollution in the relevant neighbourhood is less than 3 % of the air quality standard of 100 ·g/m^3 and thus can be regarded as not relevant. Mitigation measures regarding the existing installations are not recommended. Scenario 2 has no relevant impact on the NOx emissions of the refinery.	
SO_2	350 kg/h	1,9 kg/t	The origin of SO_2 is the incineration of fuel containing sulphur. The sulphur balance is entirely driven by the amount of sulphur in the imported crude. With a 25 % share of low-sulphur Forcados the total sulphur input to the refinery will be about the same as for Scenario 1. Because of the improved hydrotreating the overall SO_2 emission of the refinery is expected to double from approx. 180 to 350 kg/h. The World Bank target of 0,5 kg/t will be clearly missed for the refinery. Additional desulphurisation measures should be applied.	
VOC	325 kg/h	n.a.	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 with fugitive emissions from the process and direct emissions from tanks as the most important contributors. Including the tankfarms adjacent to the refinery the VOC emissions are highly relevant in the vicinity of the refinery. Scenario 2 would cause significantly higher VOC emissions (approx. + 70 kg/h compared to the existing situation) because of the higher tank farm throughput by imported products. Emission reduction should be considered.	
Wastewater	COD: 30 kg/h	COD: 0,17 kg/t	The refinery is equipped with a primary wastewater treatment (API separator) only . 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. Scenario 2 has no relevant impact on the quality of the wastewater.	
Waste	800 t/y	0,5 kg/t	Oily sludge mainly from the API separators are the most relevant source of waste. The relatively low quantity is due to the low complexity and the insufficient wastewater treatment. 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. Future constraints could come directly from legal requirements but also from offtakers, who might face emissions problems with their facilities. For Scenario 2 the relative waste production is assumed to remain unchanged.	
Land Use			Apart from new jetties (Scenario 1) Scenario 2 does not require additional land or would cause any severe land use planning problems.	
Safety			Scenario 1 and 2 require a significant increase in unloading, storage	



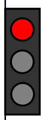
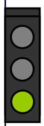
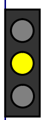
			and loading operations. Unloading and loading operations are manual to a significant extend and include the movement of tank ships and tank vehicles. The probability of misoperation is significantly higher than in continuously operated process plants. Thus, the overall risk of the total refinery operations at the given location will increase significantly. Consequently, care has to be taken to design and manage the new installations and operations in a safe way. The loading and storage area is at the eastern side of the refinery complex and far away from densely populated areas, the location of the existing and additional installations is acceptable under this point of view.	

1.2 Scenario 2: Moderate Improvement of the existing ERL Refinery (1.6 MM t/y)

This Scenario is focussed on ways to initially increase the Distillate output and operating efficiencies, without major investment in new facilities. The basis is the existing ERL refinery operation, but with possibly new (distillate rich) crude oils in the crude oil feedstock slate, like Forcados, Nat Gas condensate and possibly other Mid East crude oils.

- Debottlenecking of the existing Crude Distillation Unit overhead and rectification and stripping section.
- Debottlenecking of the Vacuum Distillation Unit by adjusting the vacuum and condensing section.
- Increase the Platformer capacity and severity of the process
- Return the current inoperative Mild Hydro Cracking unit back in service at lower pressure and in a more hydrotreating than cracking service for very light Vacuum Gasoils only
- Improve the power generating utilities
- Different crude oil types, with better performance to distillate products

Parameter air emissions	Quantity	Quantity per capacity	Impact	
NOx	30 kg/h	0,18 kg/t	NOx is emitted from incineration processes such as furnaces, boilers and engines. The refinery does not apply any specific NOx abatement technologies. Due to the low complexity of the refinery the overall furnace capacity is low related to more complex refineries. Although dedicated lownox burners are not applied the contribution to the overall NOx air pollution in the relevant neighbourhood is less than 3 % of the air quality standard of 100 ·g/m^3 and thus can be regarded as not relevant. Mitigation measures regarding the existing installations are not recommended. Scenario 2 has no relevant impact on the NOx emissions of the refinery.	
SO2	350 kg/h	1,9 kg/t	The origin of SO_2 is the incineration of fuel containing sulphur. The sulphur balance is entirely driven by the amount of sulphur in the imported crude. With a 25 % share of low-sulphur Forcados the total sulphur input to the refinery will be about the same as for Scenario 1. Because of the improved hydrotreating the overall SO_2 emission of the refinery is expected to double from approx. 180 to 350 kg/h. The World Bank target of 0,5 kg/t will be clearly missed for the refinery. Additional desulphurisation measures should be applied.	
VOC	325 kg/h	n.a.	There are no emission reduction techniques in place. The refinery is a relevant VOC polluter in the southern Chittagong area. Contrary to	

Parameter air emissions	Quantity	Quantity per capacity	Impact	
			NOx and SO_2 VOC emission come from a large number of very different sources with fugitive emissions from the process and direct emissions from tanks as the most important contributors. Including the tankfarms adjacent to the refinery the VOC emissions are highly relevant in the vicinity of the refinery. Scenario 2 would cause significantly higher VOC emissions (approx. + 70 kg/h compared to the existing situation) because of the higher tank farm throughput by imported products. Emission reduction should be considered.	
Wastewater	COD: 30 kg/h	COD: 0,17 kg/t	The refinery is equipped with a primary wastewater treatment (API separator) only 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. Scenario 2 has no relevant impact on the quality of the wastewater.	
Waste	800 t/y	0,5 kg/t	Oily sludge mainly from the API separators are the most relevant source of waste. The relatively low quantity is due to the low complexity and the insufficient wastewater treatment. 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. Future constraints could come directly from legal requirements but also from offtakers, who might face emissions problems with their facilities. For Scenario 2 the relative waste production is assumed to remain unchanged.	
Land Use			Apart from new jetties (Scenario 1) Scenario 2 does not require additional land or would cause any severe land use planning problems.	
Safety			Scenario 1 and 2 require a significant increase in unloading, storage and loading operations. Unloading and loading operations are manual to a significant extend and include the movement of tank ships and tank vehicles. The probability of misoperation is significantly higher than in continuously operated process plants. Thus, the overall risk of the total refinery operations at the given location will increase significantly. Consequently, care has to be taken to design and manage the new installations and operations in a safe way. The loading and storage area is at the eastern side of the refinery complex and far away from densely populated areas, the location of the existing and additional installations is acceptable under this point of view.	

1.3 Scenario 3: Modest modernization and increase of production capacity at the current ERL refinery site (4.7 MM t/y)

This scenario will recommend, where required, improvements, modifications and adjustments to the ERL refinery configuration with a view to enhance the technical and in particular the volumetric operation of the refinery. This scenario will include the Balancing, Modernizing, Replacing and Expansion (BRME) of the facility. There will be no major conversion units and just an essential increase in Crude Oil processing capacity.

- New Crude Distillation Unit (CDU)
- Redesign of existing Vacuum Distillation Unit

- New Continuous Catalyst Regeneration Reformer (CCR)
- New Isomerisation Unit
- Return the current inoperative Mild Hydro Cracking unit back in service at lower pressure and in a more hydrotreating than cracking service for very light Vacuum Gasoils only
- Improvement the power generating utilities
- Improvement of the oil/water separation
- Different crude oil types, with better performance to distillate products

Parameter air emissions	Quantity	Quantity per capacity	Impact
NOx	35 kg/h	0.06 kg/t	NOx is emitted from incineration processes such as furnaces, boilers and engines. The existing CDU is the most relevant individual NOx source of the refinery; it will be replaced by a new CDU. Although the production capacity is more than three times of the existing unit, the furnace capacity will only double from 30 to 60 MW due to increased efficiency. The new CCR Reformer and the Isomerisation Unit will add some additional 22 MW. It is suggested to apply lownox burnes for the new units; the total NOx emission would increase from approx. 26 to 35 kg/h. The NOx emission factor related to the new production capacity would be less than 0.1 kg/t. The NOx ground level concentration caused by the refinery would increase to some limited extend but would still be irrelevant.
SO2	400 kg/h	0,7 kg/t	The origin of SO_2 is the incineration of fuel containing sulphur. The sulphur balance is entirely driven by the amount of sulphur in the imported crude. With 40 % of the crude as low-sulphur Forcados the average sulphur content is approx. 0,75 %. This effect and the improved efficiency of the crude distillation will bring the specific emissions down to 0,7 kg/t. The World Bank target of 0,5 kg/t is still missed for the refinery. Additional desulphurisation measures should be applied.
VOC	325 kg/h	n.a.	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 with fugitive emissions from the process and direct emissions from tanks as the most important contributors. Including the tankfarms adjacent to the refinery the VOC emissions are highly relevant in the vicinity of the refinery. Scenario 3 would cause significantly higher VOC emissions (approx. + 150 kg/h compared to the existing situation) because of the higher tank farm throughput by imported and produced products. Emission reduction should be considered.
Wastewater	COD: 24 kg/h	COD: 0,05 kg/t	The refinery is equipped with a primary wastewater treatment (API separator) only. For Scenario 4 it can be expected that the total wastewater quantity will increase from 50 m^3/h to approx. 120 m^3/h. As part of the Scenario 3 the existing oil/water separation and the wastewater treatment will be improved by applying at least a secondary wastewater treatment unit to comply with the Bangladesh COD/BOD concentration limit.
Waste	4700 t/y	1 kg/t	Due to the increasing complexity of the refinery and the improvement of the wastewater treatment facilities it is assumed that the specific waste quantity will increase to approx. 1 kg/t. For the time being 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

Parameter air emissions	Quantity	Quantity per capacity	Impact	
			additional product. It is highly questionable if this way of disposal will still be feasible with significantly increasing quantities. Constraints could come directly from legal requirements but also from offtakers, who might face emissions problems with their facilities. Mitigation measures should be evaluated in case of implementation of the scenario.	
Land Use			Scenario 3 implies new process units and additional land use. It is assumed for this scenario that the new units can be located within the perimeter fence of the existing site. There are some potential areas for extension available at the site, however, these areas are mostly located south of the existing unit realatively close to the existing housing area. The minimum safety distance of 200 m is already not complied with - future extension has to be checked carefully also under this aspect.	
Safety			Apart from the safety distance considerations mentioned above the new units will be designed according to best practice also regarding process safety. The additional risk for the neighbouring housing areas are acceptable. Special care has to be taken in designing and arranging the new LPG sphere, because this would be the most safety relevant single item of the expansion. The additional impacts of the improved crude storage tanks and logistics have been mentioned under Scenario 1.	

1.4 Scenario 4/5: Full modernization of ERL refinery with addition of new units (6 MM t/y) or new refinery

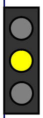
This Scenario will take both capacity expansion and yield improvement at the existing ERL location into account. Scenario 5 is a completely new refinery at a location that still has to be identified - the environmental impacts are similar to Scenario 4.

- Add to the existing ERL configuration at Chittagong a second new Crude Distillation Unit (CDU) of 100 mbpd capable to produce 6 million tons oil products per year.
- Add a new Vacuum Distillation Unit (VDU) capacity,
- A new CCR Platformer, and for the Light Naphtha an Isomerisation Unit also capable to take the stripped gas condensates from the Gas fields besides the CDU light naphtha. (as was proposed in Scenario 3)
- A new Hydrodesulphuriser, to desulphurise all CDU and Visbreaker/ Thermal Cracked produced distillates to at least 350 ppm sulphur.
- Single Stage or 2 Stage Recycle Mild Hydrocracker capable to process an extra Diesel cut from the Vacuum Gasoil fraction 375-to 430 deg C .
- A new Hydrogen production unit.
- A new Thermal Cracker to be fed with Vacuum Residue.
- Amine Absorber/regenerator units and Sulphur recovery units for adequate sulphur removal .
- New and reliable power generation system based on a Cogen efficient Combined Heat Power Gas turbine.

type	unit	fuel	Thermal capacity	flue gas	emission concentration mg/m³		emission flow rate kg/h		
			MW	m³/h	NOx	SOx	NOx	SOx	VOC

furnace	crude distillation	oil	95	95.000	250		24	65	
furnace	vacuum distillation	gas	20	20.000	150		3	14	
furnace	visbreaker thermal cracker	gas	50	50.000	150		8	35	
furnace	CCR and isomerisation	gas	25	25.000	150		4	18	
furnace	Hydrocracker, hydrogen	gas	60	60.000	150		9	42	
furnace	hydrodesul-phurisation	gas	23	23.000	150		3	16	
gas turbine	gas turbines	gas	50	50.000	150		8	35	
reactor	sulphur recovery							200	
flare	flare	flare gas		10.000	150		1,5	7	10
gas turbine	utilities	gas	50	120.000	150		18	35	
API separator	utilities								20
crude storage	tank farm								50
light products storage	tank farm loading								400
diffuse emissions	refinery								340
total							**78,5**	**467**	**810**

Parameter air emissions	Quantity	Quantity per capacity	Impact
NOx	80 kg/h	0.12 kg/t	NOx is emitted from incineration processes such as furnaces, boilers and engines. Most of the furnaces will be new and equipped with low nox burners. In this case the refinery would comply with best practice. Due to the increased capacity and complexity of the refinery the total NOx emission is about four times higher compared to the base case. The NOx ground level concentration would still be acceptable. Further mitigation is not required.
SO_2	470 kg/h	0.7 kg/t	The origin of SO_2 is the incineration of fuel containing sulphur. The sulphur balance is entirely driven by the amount of sulphur in the imported crude. With 40 % of the crude as low-sulphur Forcados the average sulphur content is approx. 0.7 %. This effect and the additional sulphur recovery will bring the specific emissions down to 0.7 kg/t, which is in line with the World Bank targets (0.5/1.0 for hydroskimming/conversion refineries). The maximum ground level concentration would be at 20 - 30 ·g/m^3 - this is acceptable as long as there are no other relevant sources in the neighbourhood. If further mitigation is required or not has to be checked based on the actual conditions.
VOC	810 kg/h	1.2 kg/t	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 with fugitive emissions from the process and direct emissions from tanks as the most important contributors. Including the tankfarms adjacent to the refinery the VOC emissions are highly relevant in the vicinity of the refinery. Scenario 4/5 would cause significantly higher VOC emissions (approx. + 70 kg/h compared to the existing situation) because of the higher tank farm throughput by imported and produced products. Emission reduction should be considered.
Wastewater	COD: 30 kg/h	COD: 0,06 kg/t	The refinery is equipped with a primary wastewater treatment (API separator) only. For Scenario 4/5 it can be expected that the total wastewater quantity will increase from 50 m^3/h to approx. 150 m^3/h. As part of the Scenario 4/5 the existing oil/water separation and the wastewater treatment will be improved by applying secondary wastewater treatment to comply with the Bangladesh COD/BOD concentration limit.
Waste	6000 t/y	1 kg/t	Due to the increasing complexity of the refinery and the improvement of the wastewater treatment facilities it is assumed that the specific waste quantity will increase to approx. 1 kg/t. For the time being 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. It is highly questionable if this way of disposal will still be feasible with significantly increasing quantities. Constraints could come directly from legal requirements but also from offtakers, who might face emissions problems with their facilities. Mitigation measures should be evaluated in case of implementation of the scenario.
Land use			Scenario 4 implies new process units and significant additional land use. It is assumed for this scenario that the new units can be located within the perimeter fence of the existing site or at adjacent locations. There are some potential areas for extension available at the site, however, these areas are mostly located south of the existing unit realatively close to the existing housing

Parameter air emissions	Quantity	Quantity per capacity	Impact	
			area. The minimum safety distance of 200 m is already not complied with - future extension has to be checked carefully also under this aspect. In case of scenario 5 a completely new site has to be developped. In this case sufficient safety distances between the refinery and housing areas should be taken care of and maintained by systematical land use planning.	
Safety			Apart from the safety distance considerations mentioned above the new units will be designed according to best practice also regarding process safety. The additional risk for the neighbouring housing areas are acceptable. As a consequence of the sulphur recovery there will be process streams with high concentrations of H_2S. H_2S is highly toxic and has to be considered as an additional risk compared to the existing situation.	

2. General Recommendations

The following general recommendations are not related to any specific technical recommendation scenario. These recommendations should be implemented for the current operations as well as for any future changes according to any recommended scenario.

2.1 HSE Management System

Recommendation:	***Implement a formalised management system for health, safety and environment.***

HSE management system (health, safety and environment) refers to the management of an organisation's HSE programs in a comprehensive, systematic, planned and documented manner. It includes the organisational structure, planning and resources for developing, implementing and maintaining policy for environmental protection.

An HSE Management System:

- Serves as a tool to improve environmental and process safety performance
- Provides a systematic way of managing an organisation's environmental affairs
- Is the aspect of the organisation's overall management structure that addresses immediate and long-term impacts of its products, services and processes on the environment
- Gives order and consistency for organisations to address environmental concerns through the allocation of resources, assignment of responsibility and ongoing evaluation of practices, procedures and processes
- Focuses on continual improvement of the system
- The HSE Management System should be set up according to international standards such as ISO 14000.
- For ERL and also for the marketing operation it should consist of the following main elements:

2.1.1 Environmental management

Air emissions

Emission Inventory

Each operating unit should keep an inventory of all relevant emission sources into the atmosphere. The inventory should include the following elements:

- general description short characterisation of each emission source
- technical identification of the source (equipment tag number)
- source height
- emission temperature

- type of process which causes the emission
- operating time (continuous, periodically)
- total flue gas flow (m^3/h dry, normal conditions)
- concentration of relevant air pollutants
- emission flow rate

Emission data can be measured directly or derived from vendor data or other technical sources. Emissions from tanks and loading facilities shall be determined by applying relevant standard procedures (e.g. API Publication 2518, Manual of Petroleum Measurement Standards Chapter 19 - Evaporative Loss Measurement - Section) or computer programmes (e.g. EPA TANK program).

Fugitive emissions from process units especially from flanges, valves, rotary equipment etc. can be determined by estimating the number of equipment and multiplying by emission factors.

Emissions from flares can be determined by estimating the total flare gas and multiplying by emission factors.

The emission factors should be taken from recognized sources (European Environmental Agency (EEA), U.S. Environmental Protection Agency (US EPA)) or from vendor data. The actual data source should be given.

Emissions shall be monitored continuously only in case of statutory requirements. In all other cases the site management decides on which sources will be measured after start-up only, or periodically.

The inventory shall include emissions from ground or elevated flares, incinerators or other equipment that serve multiple units. The inventory shall allow for allocating the emissions to the originating process unit.

Relevant air pollutants that should be covered by the inventory are:

- NOx (NO2 plus NO calculated as NO2)
- SO_2
- CO
- non-hazardous VOC (volatile organic compounds excluding hazardous air pollutants)
- specified hazardous air pollutants (HAPs) such as specific cancerogeneic hydrocarbons benzene

Ground level concentrations

The site shall be aware of the actual ground level concentrations of relevant air pollutants in the area where the plant is located. A system shall be set up to collect such information from governmental bodies or any other relevant sources. Ground level concentration measurements or dispersion calculations by the site itself are not required unless there are any statutory requirements.

Wastewater

Inventory

The operating site should keep an inventory of all sources of wastewater and all discharges into waterbodies or external sewage systems. The inventory shall include the following elements:

- Source of wastewater that are discharged from the site
- Volumes and components of each waste water stream

Relevant components or parameters are:

- COD
- BOD
- oil
- components that are required by legal standards
- pH
- Temperature

Analytic measurements should be performed for the relevant components on a regular basis.

Waste

Inventory

Each operating site should maintain an inventory covering:

- general description of the individual waste
- quantities (t/y)
- classification (hazardous/non hazardous)
- treatment and disposal (short technical description)
- costs of disposal

Soil and Groundwater

Inventory

Each operating unit / site should keep an inventory of relevant environmental risks. The inventory shall include the following elements:

- Groundwater table
- Groundwater stream direction
- Sensitive areas in the relevant neighbourhood (drinking water production)
- Operations with specific risks of polluting open waterbodies

Environmental Noise

Inventory

The site should define relevant points in the neighbouring housing areas. At these points the sound level of the operations will be measured, documented and assessed against statutory requirements.

Management of change

The inventory shall be kept as-built and integrated into the existing operational management of change procedures. For large projects or new plants emission inventories shall be set up during the impact assessment process.

Continuous improvement

The site is committed to apply the best available techniques (BAT) as far as economically feasible.

"Best" for the protection of the environment and society as a whole including consideration of cross-media impacts and cost-benefit aspects

"Available" thus allowing implementation, under economically and technically viable conditions, taking into consideration e.g. the remaining life time of a plant unit

"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.

The technical criteria for selecting a technique include:

- proven operation
- proven reliability
- availability
- long term viability, taking into account the existing plant and planned development
- availability of alternatives, (e.g., how does the technique compare with alternative options).

There are national and international organisations, which collect and publish information on BAT e.g. for the hydrocarbon processing industry. Such information shall be used as a basis for the determination of techniques to be applied in a specific case unless there are specific legal requirements.

Based on this information and on the inventories, measures to improve environmental protection shall be identified.

Reporting, auditing and review

The data from the inventories, together with the environmental improvement plan, should be published on a regular basis - normally yearly -, audited by internal or external auditors and formally reviewed by the management.

2.1.2 Safety management

Organisation and personnel

Roles and responsibilities of personnel involved in the management of major hazards at all levels in organisation have to be defined clearly and in writing.

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. A procedure should be implemented to identify safety relevant units or safety relevant changes the have to be evaluated.

Operational control

Adoption and implementation of procedures and instructions for safe operation including inspection and maintenance, of plant, processes, equipment and temporary stoppages;

Management of change

Adoption and implementation of procedures for planning modifications to, or the design of new installations, processes and storage facilities;

Planning for emergencies

Adoption and implementation of procedures to identify foreseeable 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;

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 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;

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;

2.2 Sulphur balance management

Recommendation:	*Implement a continuous quantitative sulphur balance management with a special focus on sulphur emissions of the refinery and from the products.*

The management of sulphur emissions can be handled as part of the environmental management; because of its crucial importance for the total emission it will be discussed in some more detail here.

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 Fluid Catalytic Cracking (FCC) unit and the sulphur recovery are additional major sources of SOx emissions - ERL has no FCC but the recommended Scenarios 4 and 5 do comprise a sulphur recovery unit (SRU).

The SO_2 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 SO_2 sources such as the incineration of high sulphur tailgases from the SRU.

It is very costly to control the refinery emissions by secondary methods such as flue gas scrubbing or by desulphurisation of fuel oil. Both methods are not considered best available technology because their cost/benefit ratio is low - best available technique still is finding an appropriate balance between

- crude sulphur content
- sulphur recovery
- applying natural gas as refinery fuel

SO_2 reduction is looking at the refinery as a whole and not at individual emission sources. Consequently, refinery SO_2 emissions are usually assed by assuming that the total refinery is one single source - the so-called bubble concept.

There are two different bubble concepts:

- Concentration bubble; SO_2 emissions are expressed as a fictive average concentration of SO2 in the fictive total fluegas of the refinery, which can be calculated from the fuel consumption.
- Emission factor bubble: Here the SO_2 emission is calculated as SO_2 emitted mass flow related to the total crude input.

There is some historical justification for the concentration bubble concept, however, the total flue gas quantity increases with decreasing energetic efficiency of the refinery and a certain concentration limit is easier to achieve for a refinery with a lower energetic efficiency. The emission factor bubble is completely independent of the energetic efficiency of the refinery and is therefore used in this paper.

The sulphur balances for the recommended scenarios are given in the following table:

Scenario 1	S	quantity		S		S	quantity		S
	%	t/y	%	t/y		%	t/y	%	t/y
Murban	0,72	555.900	44	4.002	fuel oil+bitumen	3,20	360.000	29	11.520
Arab light	1,78	610.700	48	10.870	distillates	0,3	662.000	53	1.986
Forcados	0,12	0	0	0	gasolines+lpg	0,05	216.000	17	108
Gas condensate	0,01	108.400	9	11	total S in products		1.238.000		13.614
					losses				1.270
Total	**1,17**	**1.275.000**		**14.884**	losses per capacity	kg/t			1,00
Scenario 2	**S**	**quantity**		**S**		**S**	**quantity**		**S**
	%	t/y	%	t/y		%	t/y	%	t/y
Murban	0,72	297.400	19	2.141	fuel oil+bitumen	2,90	440.000	29	12.760
Arab light	1,78	766.700	48	13.647	distillates	0,2	880.000	57	1.760
Forcados	0,12	400.200	25	480	gasolines+lpg	0,01	226.000	15	23
Gas condensate	0,01	136.100	9	14	total S in products		1.557.000		14.543
					losses				1.740
Total	**1,02**	**1.600.400**		**16.282**	losses per capacity	kg/t			1,09
Scenario 3	**S**	**quantity**		**S**		**S**	**quantity**		**S**
	%	t/y	%	t/y		%	t/y	%	t/y
Murban	0,72	1.161.400	26	8.362	fuel oil+bitumen	1,90	1.421.000	32	26.999
Arab light	1,78	1.340.100	30	23.854	distillates	0,2	2.332.000	53	4.664

Scenario 1	S	quantity		S		S	quantity		S
	%	t/y	%	t/y		%	t/y	%	t/y
Forcados	0,12	1.786.800	40	2.144	gasolines+lpg	0,01	648.000	15	65
Gas condensate	0,01	178.700	4	18	total S in products		4.401.000		31.728
					losses				2.650
Total	**0,77**	**4.467.000**		**34.378**	losses per capacity	kg/t			0,59
Scenario 4/5	**S**	**quantity**		**S**		**S**	**quantity**		**S**
	%	t/y	%	t/y		%	t/y	%	t/y
Al Shaheen	2,37	600.000	10	14.220	fuel oil+bitumen	2	1.069.300	18	21.386
Murban	0,72	960.000	16	6.912	distillates	0,035	3.851.000	66	1.348
Arab light	1,78	1.800.000	30	32.040	gasolines+lpg	0,01	923.000	16	92
Forcados	0,12	2.400.000	40	2.880	S from SRU	0,4			16.948
Gas condensate	0,01	240.000	4	24	total S in products		5.843.300		39.774
					losses				2.082
Total	**0,70**	**6.000.000**	**100**	**41.856**	losses per capacity	kg/t			0,35

Calculating the refinery air emissions from sulphur is not very accurate at this stage. It can be assumed that most of the balancing losses are air emissions because the use of oil and gas from the process as fuel in the refinery is the most relevant balancing loss, however not the only one. The accuracy is also limited because here a small figure is calculated from the difference of larger figures.

Nevertheless, the general trends become obvious from these preliminary sulphur balances:

In Scenario 2 the additional total crude capacity is at least partially compensated by increasing the share of low S crude. At the same time the slight increase of hydrogenation in the refinery reduces the total S in the products but leaves the refinery with additional S emissions, because no sulphur recovery will take place.

In Scenario 3 the total capacity is more than doubled, whereas the S content in the crude is further reduced by a further increase of low S crude. The total losses rise in absolute figures but in relation to the capacity the losses decrease.

Scenario 4/5 includes sulphur recovery - sulphur losses decrease in absolute figures as well as capacity related.

The sulphur balances show that the sulphur emissions have to be carefully balanced mainly by controlling the input sulphur but also by the sulphur content in products and by sulphur recovery. Deviating sulphur contents of the crude would change the picture completely.

The World Bank standard for SO_2 emissions is 0,5 kg/t for a hydroskimming and 1 kg/t for a conversion refinery. To compare these figures with the S losses given in the S balance tables, the S losses have to be multipied by 2 to convert S into SO_2. Scenarios 1 and 2 would not be acceptable without further measures, Scenario 4/5 is in full compliance and Scenario 3 is somewhere in between.

To reduce suplphure emissions further possible mitigation measures are:

- Increase low S crude share in the total crude
- Sulphur recovery from high S process streams

Both measures are described and discussed in the technical description of the Scenarios.

Theoretically flue gas treatment - e.g. absorption by caustic washing - is another alternative. Flue gas treatment is usually applied for power stations in Europe that burn high S coal; in refineries it is more or less not applied because there is normally a multitude of different flue gases from individual furnaces, which makes the treatment very costly. Apart from that, the SO_2 concentration in refinery flue gases is generally lower compared to power stations because of sulphur balancing, which is no option for a power station.

Depending on the technical details of the selected scenario it also has to be discussed, whether or not the tailgas from the sulphur recovery still needs further treatment. According to the actual definitions of Scenario 4/5 tailgas treatment is not recommended.

Tail gas from a Sulphur Recovery Unit contains sulphur oxides and hydrogen sulphide, totalling up to 3 % of total sulphur intake for a plant with a yield of 97 %. Improvement of the yield and consequently reduction of sulphur emissions can be obtained through two principal technologies and/or a combination of them:

- addition of a third Claus reactor
- addition of a Tail Gas Treatment Unit

Tail gas treatment increases the total sulphur recovery to some 98-99.99 %. The most relevant processes are:

In a Shell Claus Off-gas Treating (SCOT) unit the Claus tail gas is selectively hydrogenated to H_2S, which is separated from the gas stream in an amine absorber. The loaded amine is routed to a regenerator where H_2S is stripped off and routed back to the Claus unit. A stand-alone SCOT has its own amine stripper, while in a cascaded SCOT the loaded amine is recombined with other amine streams and washed in a common column.

In a Super Claus unit, the tail gas is led through a reactor with a selective oxidation catalyst, which converts H_2S with excess oxygen to sulphur.

The Clauspol process is based on the Claus reaction (hydrogen sulphide plus sulphur dioxide reacting to sulphur and water). The reaction takes place in a column with packed beds, with the gas entering from the bottom of the column while a solvent with catalyst is distributed in the top of the column. The sulphur is collected at the bottom of the column.

The Sulfreen process is also based on the Claus reaction. Here the sulphur produced is adsorbed on an active alumina based catalyst. Two reactors are used, while one is in the adsorbing mode, the other reactor is regenerated by stripping off the sulphur.

2.3 NOx emission reduction

Recommendation:	*New furnaces and boilers should be equipped with low NOx burners.*

As shown in the Assessment Report, the refinery is not a relevant source of NOx emissions in the Chittagong area. For the emission estimate of the recommended scenarios it is assumed that Low-NOx burners will be applied for new equipment.

Low-NOx burners 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. Ultra-low-NOx burners add internal recirculation of flue gases to the features of the low-NOx burner enabling further NOx reductions.

Low-NOx burners achieve NOx reduction performances of 40 -60 % for gaseous fuels and 30 - 50 % for liquid fuels. Ultra-low-NOx burners applied to process heaters and boilers can achieve a 60 - 75 % reduction of NOx emissions.

Low-NOx burners achieve NOx concentrations of approx. 150 mg/m³ for refinery gas and 250 mg/m³ for liquid fuel oil.

For oil firing there is a direct link between NOx and particulates i.e. reduction in NOx as the flame temperature falls will lead to an increase in particulates. For low-NOx fuel oil burners, as with conventional fuel oil burners a further reduction of thermal NOx results in an increase in carbon particulates. CO emissions are also increased.

Application is straightforward for new installations of both fired heaters and boilers. Some liquid fuels are not suitable for the latest generation of low-NOx burners and some older fired heaters are fitted with large high intensity burners which cannot be retrofitted with new low-NOx burners. Retrofitting of low-NOx burners depends on the furnace design and may be simple, difficult or - because of the increased flame volume - impossible without changing the furnace. For instance the increased length of low-NOx burners may restrict applicability in furnaces built low above-ground. NOx abatement on older furnaces and boilers may also be less effective due mainly to the need to avoid flame impingement on the furnace tubes.

For new installations the additional costs of low-NOx burners are irrelevant and there are no additional operation costs.

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.

2.4 VOC emission reduction

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).

The total quantity of VOC emission losses can be as high as 0.1 % of the throughput; at least some measures can be economically feasible. There are numerous techniques to minimise VOC emissions - not all of them are applicable in a retrofit situation.

2.4.1 LDAR programme

Recommendation:	*Implement an LDAR (Leak Detection and Repair) programme to reduce VOC emissions from process units.*

LDAR - Leak Detection and Repair - is a powerful tool to identify and minimise VOC emissions from a refinery. 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.

The method is described in the US American standard 40 CFR Part 60, Appendix A, Method 21.

LDAR is applied to valves, pumps, compressors, pressure re-lief valves, flanges, connectors, and other piping components. Valves are usually the single largest source of fugitive emissions. Emissions from any single piece of equipment are usually small. Based on the large number of equipment components LDAR requirements, however, cumulative emissions can be very large.

LDAR programmes are generally comprised of four processes. Regulations vary but usually require refineries to:

- Identify components to be included in the program;
- Conduct routine monitoring of identified components;
- Repair any leaking components;
- Report monitoring results.

The LDAR programme should be developed and tailored to suit the situation concerned, using appropriate techniques, frequencies and priorities. It should provide estimates of fugitive VOC releases for monitoring returns and enable action to be taken to minimise releases. A LDAR contains the following elements:

- type of measurement (e.g. detection limit of 500 ppm for valves and flanges. against the interface of the flange)
- frequency (e.g. once or twice a year)
- type of components to be checked (e.g. pumps. control valves, heat exchangers, connectors, flanges)
- type of compound lines
- what leaks should be repaired and how fast the action should be taken

The equipment required for LDAR equipment is relatively simple and inexpensive, the costs are mainly for personell. LDAR is mostly contracted as an external service, however, there is no problem in performing such programmes by the refinery personell themselves.

The refinery according to scenario 3 - 5 could have fugitive emissions in the order of magnitude of 100 - 200 kg/h, which is 800 - 1600 t/y. If only 50 % of these losses can be reduced by LDAR, the annual benefit would be 240,000 to 500,000 USD, which is more than enough to cover the costs of the programme as such.

2.4.2 VOC recovery

Recommendation:	*Consider the technical and economical feasibility of VOC recovery at storage and loading units.*

Vapour recovery units (VRU) are installations designed for the emission reduction of volatile organic compounds (VOC) which are emitted during loading and unloading operations of light products. Generally light products are products with a vapour pressure of more than 10 - 15 mbar, i.e. Diesel, Kerosine, fuel oil etc. are generally not recovered, because the cost/benefit ratio is unsatifactory.

Crude oil is unloaded from ships or barges into floating roof tanks; there is no displaced gas phase in this case, so recovery is not necessary or possible also in this case. Vapour recovery will be restricted to the handling of light products.

Several commercial techniques are available for the recovery of VOC:

- Condensation: The hydrocarbons are condensated from the waste gas stream by cooling with cooling or chilled water. The efficiency depends on the cooling temperature, the equipment is simple, stringent emission standards cannot by complied with.

- Absorption: The vapour molecules dissolve in a suitable absorption liquid (water, lyes, glycols or mineral oil fractions such as reformate). As long as no regeneration of the liquid is required, the method is also relatively simple, stringent emission standards cannot by complied with.
- Adsorption: The vapour molecules adhere physically to activate sites on the surface of solid materials, like activated carbon or zeolite. Mainly due to the requirement of regeneration of the adsorbent, the method is effective and expensive.
- Hybrid systems: Combinations of the VRU are on the market, which are able to meet very low emissions standards. Examples are cooling/ybsorption and compression/ybsorption/membrane separation.

The economics of vapour recovery are governed by the emissions requirements. In most cases a cost-effective method is applied as first stage to recover the bulk of hydrocarbons, followed by a second step to treat the remaining tail gas according to emission control requirements. In many case the first step is economically feasible, i.e. the cost of the recovery is recovered by the benefit from the recovered product. The second step recovers only limited quantities and would never be economical feasible.

For ERL it is recommended to apply a one-stage vapour recovery system that is designed for economic feasibility only. Also here efficiencies of clearly over 90 % can be achieved, which would be a significant improvement of the situation.

The technique to be selected should be either condensation or absorption. For absorption a hydrocarbon available from the refinery could be applied as an absorbent and the loaded absorbent could be blended into an appropriate product without regeneration.

To minimise the total vapour a balancing system should be applied. There are some restrictions in a refinery, as e.g. the vapour that is displaced in product tanks filled from process units cannot be balanced. Balancing is more or less restricted to loading processes. Vapour recovery at truck top loading points are available but require significant changes for the loading station. For that reason, in a first stage the truck loading could be left out and integrated later, when those installations will be replaced by new ones.

2.5 Flare gas recovery

Recommendation:	*Consider the technical and economical feasibility of a flare gas recovery system.*

Flares are designed for safety and environmental control of discharges from pressure safety valves or other safety related equipment, i.e. the flare system is primarily a safety equipment. Apart from that excess combustibles that cannot be utilised in the refinery are also routed to the flare. This could be excess refinery gas, displaced gas phase from tanks during tank filling, gas from pressure controllers, nitrogen/hydrocarbon mixtures from purging and blanketing or other streams that cannot easily be used because of low caloric value or low pressure.

It is best practice to minimise continuous hydrocarbon streams to the flare by routing such streams back to the process or to the heating gas system, nevertheless there are always smaller continuous or discontinuous streams that can not be used economically and are routed to the flare system. In larger refineries these remaining flare gas streams can be in the order of magnitude of 5 t/h and more.

Flare gas recovery system have been developed due to increasing requirements to control visible flaring, however, in many cases flare gas recovery systems could also be economically feasible.

The basic design of a flare gas recovery system comprises a fluid ring compressor followed by a knock out/separator vessel to collect and recycle the ring fluid and separate liquid hydrocarbons. The condensed gas can be routed to the fuel gas system of the refinery. Because of the extreme variations of the heating value of the recycled gas an effective control of the mixing of recycled flare gas and heating gas is an important part of the system. The fluid ring compressor can be replaced by an ejector system in specific cases. In case of higher sulphur concentration an amine washing step can also be integrated.

Flare gas recovery is economically feasible in many cases but in other cases it is not - depending on the total quantity, the composition and the variation of these parameters.

Typical economic data:

▪ Flare gas quantity	5 t/h	
▪ Nitrogen content	50 %	
▪ Recovered hydrocarbons to fuel gas	2.5 t/h	21,000 t/y
▪ Compressor installed electrical power	350 kW	
▪ Total investment		5,000,000 USD
▪ Depreciation, insurance, maintenance	15 %	750,000 USD/y
▪ Operating costs (el. energy)	0,10 USD/kWh	250,000 USD
▪ Total costs		1,000,000 USD
▪ Costs per hydrocarbon recovered USD/t		46.5

The costs could be further reduced by performing the project as a Clean Development Mechanism (CDM) project within the framework of the Kyoto Protocol (see next paragraph).

2.6 Clean Development Mechanism Projects (CDM)

Recommendation:	*Consider participation in the Kyoto CO_2 trading (CDM) for projects regarding emission reduction or energy saving.*

The CDM is one of the "flexibility mechanisms" that are defined in the Kyoto Protocol. The flexibility mechanisms are designed to allow so-called Annex B countries to meet their emission reduction commitments by sponsoring projects in developing countries.

Emission reduction is accomplished by projects in developing countries. These reductions are subtracted against a hypothetical baseline of emissions. The emissions baseline is the emissions that are predicted to occur in the absence of a particular CDM project. CDM projects are credited against this baseline, in the sense that developing countries gain credit for producing these emission reductions.

The economic basis for including developing countries in efforts to reduce emissions is that emission cuts are thought to be less expensive in developing countries. In developing countries, environmental regulation is generally weaker than it is in developed countries. Thus, there is greater potential for developing countries to reduce their emissions than in developed countries.

A CDM project has to follow a specific procedure:

Project Design Document (PDD): The PDD has both a prescribed format and mandatory content and provides the basis on which project approval decisions are made. Its main component, apart from a detailed description of the project activity, is an outline of a reference scenario. The scenario describes the investment that would be made and/or the business approach that would be taken in the absence of the project. This is often termed as the reference scenario. When identifying the reference scenario, available technologies, state incentive programmes and statutory requirements must be taken into account. The emissions are estimated that would result if the reference scenario occurred. The estimate is known as the baseline. The baseline is then compared with a forecast of the emissions that would occur if the project activity were implemented. This allows calculation of the emission reductions expected from the project.

A key prerequisite in the approval of a climate change project is the criterion of additionality. This requires that climate change projects only be approved if they would not have come to fruition without the incentives provided by the CDM mechanism.

Assessment/ypproval: The PDD is assessed by a certified organisation and after that registered by the CDM Executive Board. The CDM Executive Board will issue Certificates of Emission Reduction based on monitoring results, which can be sold on the free market in industrialised countries, which take part in emission trading.

The actual exchange rate for Certified Emission Reductions is in the order of magnitude of 10 to 15 EUR.

1 t of recovered hydrocarbon is equivalent to approximately 3 t of CO_2 - i.e. by taking part in the CDM a significant additional positive effect can be achieved.

2.7 Improvement of wastewater treatment

Recommendation:	*Improve wastewater treatment by applying a secondary or tertiary stage wastewater treatment unit.*

The ERL is equipped with a simple API separator for primary wastewater treatment. According to the available knowledge the Bangladesh wastewater standards - especially COD 200 mg/l and BOD 30 mg/l - cannot be achieved with primary wastewater treatment only.

Best practise for refineries worldwide is a three stage wastewater treatment:

2.7.1 Primary 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. The most relevant types are:

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.

A Parallel Plate Interceptor (PPI) is a gravity separator equipped with plates parallel to the current to promote laminar flow and reduce the separation distance. Within a PPI the combined surface area of the plates is significantly higher than the surface area of the conventional API separator, resulting in a smaller ground area. The main disadvantage is that the plates are susceptible to fouling and hence there is an increased maintenance requirement.

In a Corrugated Plate Interceptor (CPI) specially designed corrugated plate packs are placed counter current to the flow, i.e. the effluent flows downward whereas the oil flows upward to the surface. The advantages are a small surface area and increased efficiency over API and PPI equipment as the CPI can remove smaller oil droplets. The disadvantages are again the possibility of fouling and increased maintenance. The CPI is particularly suitable for installation on individual processing areas, as close as possible to the point of waste water generation. In these circumstances, there is less likelihood of fouling, the oil may be able to be recycled directly to the unit, and the load on the site effluent treatment plant is reduced.

2.7.2 Secondary treatment

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.

There are two main types known as Dissolved and Induced Air Flotation (DAF, IAF). They are generally installed downstream of separators as a secondary treatment prior to a biological process. Designed and operated correctly, they 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.

2.7.3 Tertiary treatment

Tertiary treatment is a biological treatment of effluent water based on the process in which a mixed population of micro-organisms uses 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.

Although there also some other processes, the activated sludge (AS) process is the most relevant for refineries. The activated sludge process is a dispersed or suspended growth system comprising a mass of micro-organisms constantly supplied with organic matter and, for aerobic treatment, oxygen. The micro-organisms grow in flocs, and in aerobic treatment, these flocs are responsible for the transformation of organic material into new bacteria, carbon dioxide and water, and for ammonia reduction into nitrite and nitrate. In anoxic treatment, the nitrate and nitrite are further reduced to gaseous nitrogen. The flocs are constantly being washed out of the reaction vessel to the secondary sedimentation tank or clarifier by the flow of effluent. Here they flocculate and settle under quiescent conditions. It is a characteristic of the activated sludge process that a proportion of this settled sludge is recycled back to the mixing/yeration tank to provide sufficient biomass for contaminant removal. Any excess biological solids are removed, dewatered, and sent for disposal.

2.7.4 Wastewater management

To minimise the wastewater treatment requirements some measures of managing the total amount and segregation of the individual wastewater streams should be analysed:

Sour water can be used to the maximum extend possible as desalted wash water.

Equalising tanks for the storage of waste water can be used to avoid peak loads for the wastewater treatment.

Rainwater from polluted plant areas should be collected and routed to the treatment plant. Depending on the initial degree of pollution (mainly oil), an adapted partial treatment according to a first flush scheme could be sufficient. Non-contaminated water may be discharged directly or re-used in order to save costs.

Control of surfactants in wastewater - surfactants entering the refinery wastewater streams will increase the amount of emulsions and sludges generated. Surfactants can enter the system from a number of sources including washing unit pads with detergents, caustic treatment, cleaning tank truck tank interiors or using cleaners for miscellaneous tasks.

Refinery effluents can also be treated in municipal sewage treatment plants or installations that are shared with other industries. In these cases, the effluent will normally be given primary and secondary treatment at the refinery to remove free oil before it is passed to the common installation. There can be advantages to both parties in such treatment in that the domestic sewage provides nutrients, and dilutes any surges of chemicals which are toxic to the biomedia. The common plant can benefit by receiving a reasonably constant flow to balance out peak loads. Especially at locations with no existing installations like in Chittagong this option should be checked.

2.8 Waste management

Recommendation:	Prepare for an improved waste treatment system.

Oily sludge mainly from the API separators is the most relevant source of waste at the Eastern refinery in its present state. The total sludge produced is approx. 650 t/y 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 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.

In the future and depending on the selected scenario for increasing the capacity of the refinery different problems could arise:

The current procedure of selling the sludge off as a heating medium is only possible because the legal framework in Bangladesh 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.

The upgrading of the refinery will lead to additional quantities of oily sludge because the quantity increases with the capacity of the refinery. For the 6 million t/y case there would be some 3,000 t/y of oily sludge. It is questionable, if a market is readily available for this product.

Upgrading of the wastewater treatment will produce biotreatment sludge as new kind of sludge that does not exist at the time being - the quantity will be only a little less than of oily sludges. Biotreatment sludge does not contain relevant quantities of oil but water - it will not be possible to market it as a fuel like oily sludge.

2.8.1 Sludge treatment

Treatment of sludges before disposal is applied to:

- to reduce the quantity of waste requiring disposal
- to recover the oil for recycling

The choice of whether to treat the sludge depends on many factors including the composition of the sludge and the choice of disposal route. For example, if the sludge is to be used as a fuel, it will be important to remove the water, but not the oil. Alternatively if a biosludge which is essentially oil free is to be spread on land (so-called land farming), it may be preferable to leave it wet.

Centrifugation exploits the difference in density between solids and liquids by applying centrifugal force. Two main types of decanter centrifuge can be applied at refineries: 2-phase, which yields a solids cake plus a single effluent stream (mixed oil and water); and 3-phase which yields separate oil and water streams, as well as the cake. Advantages of decanter centrifuges include resource recovery, flexibility and high volume reduction. With good operation, cake suspended solid contents of 20-40 % can be achieved. Centrifugation of sludges need not be handled by the refinery itself, but can also be contracted to specialised companies on a discontinuous basis.

Filter presses mechanically dewater sludges by pressure. The benefits are high volume reduction and recovery of oil from oily sludges. In most cases, filter aids are needed to enhance dewatering and prevent clogging of the filter but will increase waste volumes.

Heating and flocculants may also be used to enhance performance. Belt filter presses can produce a 15-20 % suspended solids filter cake but have high maintenance requirements and can have problems with the processing of oily sludge due to filter cloth blockage. In plate and frame presses the sludge is mechanically squeezed in filter-cloth lined chambers.

By sludge treatment the quantities of sludge for scenario 4/5 (6 million t/y) could be reduced to approximately 600 t/y of oily sludges and about the same quantity of biosludges.

Cost of pretreatment is approx. 50 - 100 USD/t for EU refineries, at least for oily sludges the recovered oil would compensate for these costs. In any case the pretreatment costs have to be assessed against the benefit of recovered oil and the costs that can be saved on the disposal.

2.8.2 Sludge disposal

It goes without saying that the present way of selling the sludge as a heating medium is the most feasible for the refinery. Conditions to proceed like this have to be monitored carefully, potential alternative offtakers should be identified as well their potential problems.

Depending on their processes different types of offtakers will have different problems with refinery sludges. Heavy metals is one of the most relevant problems and can be solved better at installations like cement kilns because here heavy metals are demobilised at least to some extent in the cement matrix. Another possibility is installations that are equipped with some flue gas treatment like power stations, which can cope with the additional problems caused by sludge burning.

Once the sludges cannot be sold for a positive price, it might be the economically most feasible approach to sell them for a negative price, i.e. to pay for disposal as alternative fuel. For the new biosludges it has to be expected that a positive price cannot be achieved from the very beginning.

If for whatever reason it will no longer be possible to market the sludges, appropriate ways for disposing the sludges off have to be identified:

Landfill is to deposit wastes either in specially excavated or pre-existing depressions in the ground or specially prepared sites above ground. After deposition, the wastes are covered with soil and the land is rehabilitated. Landfilling is in most cases the least costly solution but it strongly depends on the legal framework, in many EU countries simply landfilling untreated refinery sludges is not possible anymore due to hazards from mobilising contaminants from the sludges into the groundwater despite mitigation methods such as impervious membranes or layers. Some landfills require solidification of sludges to bind contaminants in cement or similar materials.

Dedicate waste incineration is high temperature oxidation which converts oily sludges into solid ash. Waste incineration plants can be operated by the refinery or by others as cooperative, commercial or municipal installations; however, this alternative is highly costly and should be taken into account not before all other solutions have turned out not feasible.