Environmental, Health, and Safety Guidelines for Natural Gas Processing

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Natural Gas Processing cover production in gas to liquids (GTL) facilities including production of methanol, as well as common intermediate production of synthetic gas known as "Syn-gas", a mixture of carbon monoxide and hydrogen. Annex A contains a description of industry sector activities. Information on EHS issues related to storage tank farms is provided in the EHS Guidelines for Crude Oil and Petroleum Product Terminals.

This document is organized according to the following sections:

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with natural gas processing, which occur during the operational phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phase(s) are provided in the **General EHS Guidelines**.

1.1 Environmental

Potential environmental aspects associated with natural gas processing include the following:

- Air emissions
- Wastewater
- Hazardous materials
- Wastes
- Noise

Air Emissions

Fugitive Emissions

Fugitive emissions in natural gas processing facilities are associated with leaks in tubing; valves; connections; flanges; packings; open-ended lines; floating roof storage tank, pump, and compressor seals; gas conveyance systems, pressure relief valves, tanks or open pits / containments, and loading and unloading operations of hydrocarbons.

The main sources and pollutants of concern include Volatile Organic Compound (VOC) emissions from storage tanks during filling and due to tank breathing; floating roof seals in case of floating roof storage tanks; wastewater treatment units; Fischer-Tropsch (F-T) synthesis units; methanol synthesis units; and product up-grading units. Additional sources of fugitive emissions include nitrogen gas contaminated with methanol vapor from methanol storage facilities; methane (CH_4), carbon monoxide (CO), and hydrogen from Syn-gas production units, and Fischer-Tropsch (F-T) or methanol synthesis units.

Recommendations to prevent and control fugitive emissions include the following:

- Regularly monitor fugitive emissions from pipes, valves, seals, tanks, and other infrastructure components with vapor detection equipment, and maintenance or replacement of components as needed in a prioritized manner;
- Maintain stable tank pressure and vapor space by:
    - Coordinating filling and withdrawal schedules, and implementing vapor balancing between tanks, (a process whereby vapor displaced during filling activities is transferred to the vapor space of the tank being emptied or to other containment in preparation for vapor recovery);
    - Using white or other color paints with low heat absorption properties on exteriors of storage tanks for lighter distillates such as gasoline, ethanol, and methanol to reduce heat absorption. Potential for visual impacts from reflection of light off tanks should be considered;
- Selecting and designing storage tanks in accordance with internationally accepted standards to minimize storage and working losses considering, for example, storage capacity and the vapor pressure of materials being stored;[2]

[2] Examples include: API Standard 620: Design and Construction of Large, Welded, Low-pressure Storage Tanks (2002); API Standard 650: Welded Steel Tanks for Oil Storage (1998), and; European Union (EU) European Standard (EN) 12285-2:2005. Workshop fabricated steel tanks for the aboveground storage of flammable and non-flammable water polluting liquids (2005). For example, according to API Standard 650: Welded Steel Tanks for Oil Storage (1998), new, modified, or restructured tanks with a capacity greater or equal to 40,000 gallons and storing liquids with a vapor pressure greater or equal than 0.75 psi but less than 11.1 psi, or a capacity greater or equal to 20,000 gallons and storing liquids with a vapor pressure greater or equal than 4 psi but less than 11.1 psi must be equipped with: fixed roof in conjunction with an internal

- Use supply and return systems, vapor recovery hoses, and vapor-tight trucks / railcars / vessels during loading and unloading of transport vehicles;
- Use bottom-loading truck / rail car filling systems; and
- Where vapor emissions contribute or result in ambient air quality levels in excess of health based standards, install secondary emissions controls, such as vapor condensing and recovery units, catalytic oxidizers, vapor combustion units, or gas adsorption media.

Greenhouse Gases (GHGs)

Significant amounts of carbon dioxide (CO_2) may be emitted from Syn-gas manufacturing, mainly from CO_2 washing, and from all combustion processes (e.g., electric power production and byproduct incineration). Recommendations for energy conservation and the management of greenhouse gas emissions are discussed in the **General EHS Guidelines**. At integrated facilities, operators should explore an overall facility approach in the selection of process and utility technologies.

Exhaust Gases

Exhaust gas emissions produced by the combustion of gas or other hydrocarbon fuels in turbines, boilers, compressors, pumps, and other engines for power and heat generation are a significant source of air emissions from natural gas processing facilities. Incineration of oxygenated byproducts at GTL production facilities also generates CO_2 and nitrogen oxides (NO_X) emissions.

Guidance for the management of small combustion processes designed to deliver electrical or mechanical power, steam, heat, or any combination of these, regardless of the fuel type, with a total, rated heat input capacity of 50 Megawatt thermal (MWth) is provided in the **General EHS Guidelines**. Guidance applicable to processes larger than 50 MWth is provided in the **EHS Guidelines for Thermal Power**.

Emissions related to the operation of power sources should be minimized through the adoption of a combined strategy which includes a reduction in energy demand, use of cleaner fuels, and application of emissions controls where required. Recommendations on energy efficiency are addressed in the **General EHS Guidelines.**

Venting and Flaring

Venting and flaring are an important operational and safety measure used in natural gas processing facilities to ensure gas is safely disposed of in the event of an emergency, power or equipment failure, or other plant upset conditions. Unreacted raw materials and by-product combustible gases are also disposed of through venting and flaring. Excess gas should not be vented but instead sent to an efficient flare gas system for disposal.

Recommendations to minimize gas venting and flaring include the following:

- Optimize plant controls to increase the reaction conversion rates;
- Recycle unreacted raw materials and by-product combustible gases in the process or utilize these gases for power generation or heat recovery, if possible;
- Provide back-up systems to achieve as high a plant reliability as practical; and
- Locate the flaring system at a safe distance from residential areas or other potential receptors, and maintain the system to achieve high efficiency.

floating roof with a liquid mounted mechanical shoe primary seal; or external floating roof with a liquid mounted mechanical shoe primary seal and continuous rim-mounted secondary seal, with both seals meeting certain minimum gap requirements and gasketed covers on the roof fittings; or closed vent system and 95% effective control device. See also American Petroleum Institute (API) Standard 2610: Design, Construction, Operation, and Maintenance of Terminal and Tank Facilities (2005).

Emergency venting may be acceptable under specific conditions where flaring of the gas stream is not appropriate. For example, in GTL processing there could be streams containing high concentrations of carbon dioxide which, if sent to a flare system, would extinguish the flare's flame; - venting of such streams to a safe atmospheric location is an acceptable option. Standard risk assessment methodologies should be utilized to analyze such situations. Justification for not using a gas flaring system should be fully documented before an emergency gas venting facility is considered.

Wastewater

Industrial Process Wastewater

Process wastewater and other wastewaters, which may be contain dissolved hydrocarbons, oxygenated compounds, and other contaminants, should be treated at the onsite wastewater treatment unit (WWTU). Recommended process wastewater management practices include:

- Prevention and control of accidental releases of liquids through inspections and maintenance of storage and conveyance systems, including stuffing boxes on pumps and valves and other potential leakage points, as well as the implementation of spill response plans;
- Provision of sufficient process fluids let-down capacity to maximize recovery into the process and to avoid massive process liquids discharge into the oily water drain system;
- Design and construction of wastewater and hazardous materials storage containment basins with impervious surfaces to prevent infiltration of contaminated water into soil and groundwater.

Specific provisions to be considered for the management of individual wastewater streams include the following:

- Amines spills resulting from the carbon dioxide alkaline removal system downstream of the Gasification Unit should be collected into a dedicated closed drain system and, after filtration, recycled back into the process provided the amine did not become contaminated as a consequence of being spilled and/or collected;
- The water effluent from the stripping column of the Fischer-Tropsch (F-T) Synthesis Unit, which contains dissolved hydrocarbons and oxygenated compounds including alcohols, organic acids and minor amounts of ketones, should be re-circulated inside the F-T Synthesis Unit in order to recover the hydrocarbons and oxygenated compounds;
- Acidic and caustic effluents from demineralized water preparation, the generation of which depends on the quality of the raw water supply to the process, should be neutralized prior to discharge into the facility's wastewater treatment system;
- Blow-down from the steam generation systems and cooling towers should be cooled prior to discharge. Cooling water containing biocides or other additives may also require dose adjustments or treatment in the facility's wastewater treatment plant prior to discharge; and
- Hydrocarbon-contaminated water from scheduled cleaning activities during facility turn-around (cleaning activities are typically performed annually and may last for a few weeks), hydrocarbon-containing effluents from process leaks, and heavy-metals containing effluents from fixed and fluidized beds should be treated via the facility's wastewater treatment plant.

Process Wastewater treatment

Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment of concentrated wastewater streams. Typical wastewater treatment steps include: grease traps, skimmers, dissolved air floatation, or oil / water separators for separation of oils and floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment, typically aerobic treatment, for reduction of soluble organic matter (BOD); chemical or biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; and dewatering and disposal of residuals in designated hazardous waste landfills. Additional engineering controls may be required for (i) containment and treatment of volatile organics stripped from various unit operations in the wastewater treatment system, (ii)advanced metals removal using membrane filtration or other physical/chemical treatment technologies, (iii) removal of recalcitrant organics, cyanide, and non biodegradable COD using activated carbon or advanced chemical oxidation, (iii) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.), and (iv) containment and neutralization of nuisance odors.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

Other Wastewater Streams & Water Consumption

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the General EHS Guidelines. Contaminated streams should be routed to the treatment system for industrial process wastewater. Additional specific guidance is provided below.

Stormwater: Stormwater may become contaminated as a result of spills of process liquids. Natural gas processing facilities should provide secondary containment where liquids are handled, segregate contaminated and non-contaminated stormwater, implement spill control plans, and route stormwater from process areas into the wastewater treatment unit.

Cooling water: Cooling water may necessitate high rates of water consumption, as well as the potential release of high temperature water, residues of biocides, and residues of other cooling system anti-fouling agents. Recommended cooling water management strategies include:

- Adoption of water conservation opportunities for facility cooling systems as provided in the **General EHS Guidelines**;
- Use of heat recovery methods (also energy efficiency improvements) or other cooling methods to reduce the temperature of heated water prior to discharge to ensure the discharge water temperature does not result in an increase greater than 3°C of ambient temperature at the edge of a scientifically established mixing zone that takes into account ambient water quality, receiving water use, assimilative capacity, etc.;
- Minimizing use of antifouling and corrosion-inhibiting chemicals through proper selection of depth for placement of water intake and use of screens; selection of the least-hazardous alternative with regards to toxicity, biodegradability, bioavailability, and bioaccumulation potential; and dosing according to local regulatory requirements and manufacturer recommendations; and
- Testing for the presence of residual biocides and other pollutants of concern to determine the need for dose adjustments or treatment of cooling water prior to discharge.

Hydrostatic testing water: Hydrostatic testing of equipment and pipelines involves pressure testing with water (generally filtered raw water) to verify their integrity and to detect possible leaks. Chemical additives (typically a corrosion inhibitor, an oxygen scavenger, and a dye) may be added. In managing hydro-test waters, the following pollution prevention and control measures should be implemented:

- Using the same water for multiple tests to conserve water and minimize discharges of potentially contaminated effluent;
- Reducing the use of corrosion inhibiting or other chemicals by minimizing the time that test water remains in the equipment or pipeline; and
- Selecting the least hazardous alternative with regards to toxicity, biodegradability, bioavailability, and bioaccumulation potential, and dosing according to local regulatory requirements and manufacturer recommendations.

If discharge of hydro-test waters to the sea or to surface water is the only feasible alternative for disposal, a hydro-test water disposal plan should be prepared considering location and rate of discharge, chemical use (if any), dispersion, environmental risk, and required monitoring. Hydro-test water disposal into shallow coastal waters should be avoided.

Hazardous Materials

Natural gas processing facilities use and manufacture significant amounts of hazardous materials, including raw materials, intermediate / final products and by-products. The handling, storage, and transportation of these materials should to be managed properly to avoid or minimize the environmental impacts from these hazardous materials. Recommended practices for hazardous material management, including handling, storage, and transport, are presented in the **General EHS Guidelines**.

Wastes

Non-hazardous Waste

Non-hazardous industrial wastes consist mainly of exhausted molecular sieves from the air separation unit as well as domestic wastes. Other non-hazardous wastes may include office and packaging wastes, construction rubble, and scrap metal. General recommendations for the management of non-hazardous waste, including storage and disposal, are presented in the **General EHS Guidelines**.

Hazardous Waste

Hazardous waste should be determined according to the characteristics and source of the waste materials and applicable regulatory classification. In GTL facilities, hazardous wastes may include bio-sludge; spent catalysts; spent oil, solvents, and filters (e.g., activated carbon filters and oily sludge from oil water separators); used containers and oily rags; mineral spirits; used sweetening; spent amines for CO_2 removal; and laboratory wastes. General recommendations for the management of hazardous waste are presented in the **General EHS Guidelines**. Industry-specific waste management practices are described below.

Spent catalysts: Spent catalysts from GTL production are generated from scheduled replacements in natural gas desulphurization reactors, reforming reactors and furnaces, Fischer-Tropsch synthesis reactors, and reactors for mild hydrocracking. Spent catalysts may contain zinc, nickel, iron, cobalt, platinum, palladium, and copper, depending on the particular process. Recommended waste management strategies for spent catalysts include the following:

- Proper on-site management, including submerging pyrophoric spent catalysts in water during temporary storage and transport until they can reach the final point of treatment to avoid uncontrolled exothermic reactions;

- Return to the manufacturer for regeneration; and
- Off-site management by specialized companies that can recover the heavy or precious metals, through recovery and recycling processes whenever possible, or who can otherwise manage spent catalysts or their non-recoverable materials according to hazardous and non-hazardous waste management recommendations presented in the General EHS Guidelines. Catalysts that contain platinum or palladium should be sent to a noble metal recovery facility.

Heavy ends: Heavy ends from the purification section of the Methanol Synthesis Unit are normally burnt in a steam boiler by means of a dedicated burner.

Noise

The principal sources of noise in natural gas processing facilities include large rotating machines (e.g. compressors, turbines, pumps, electric motors, air coolers, and fired heaters). During emergency depressurization, high noise levels can be generated due to release of high-pressure gases to flare and / or steam release into the atmosphere. General recommendations for noise management are provided in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

Facility-specific occupational health and safety hazards should be identified based on job safety analysis or comprehensive hazard or risk assessment using established methodologies such as a hazard identification study [HAZID], hazard and operability study [HAZOP], or a scenario-based risk assessment [QRA].

As a general approach, health and safety management planning should include the adoption of a systematic and structured approach for prevention and control of physical, chemical, and biological health and safety hazards described in the **General EHS Guidelines** (Occupational Health and Safety).

The most significant occupational health and safety hazards occur during the operational phase of a natural gas processing facility and primarily include the following:

- Process Safety
- Oxygen-Enriched Gas Releases
- Oxygen-Deficient Atmospheres
- Chemical hazards

Process Safety

Process safety programs should be implemented due to industry-specific characteristics, including complex chemistry reactions, use of hazardous materials (e.g., toxic, reactive, flammable, or explosive compounds), and multi-step reactions. Process safety management includes the following actions:

- Physical hazard testing of materials and reactions;
- Hazard analysis studies to review the process chemistry and engineering practices, including thermodynamics and kinetics;
- Examination of preventive maintenance and mechanical integrity of the process equipment and utilities;
- Worker training; and
- Development of operating instructions and emergency response procedures.

Oxygen-Enriched Gas Releases

Leaks of oxygen-enriched from air separation units can create a fire risk. Oxygen-enriched atmospheres may potentially result in the saturation of materials, hair, and clothing with oxygen, which may burn violently if ignited. Prevention and control measures to reduce on-site and off-site exposure to oxygen-enriched atmospheres include:

- Installation of an automatic Emergency Shutdown System that can detect and warn of the uncontrolled release of oxygen (including the presence of oxygen-enriched atmospheres in working areas[3]) and initiate shutdown actions thus minimizing the duration of releases, and elimination of potential ignition sources;
- Design of facilities and components according to applicable industry safety standards, avoiding the placement of oxygen-carrying piping in confined spaces, using intrinsically safe electrical installations, and using facility-wide oxygen venting systems that properly consider the potential impact of the vented gas;
- Implementation of hot work and permit-required confined space entry procedures that specifically take into account the potential release of oxygen;
- Implementation of good housekeeping practices to avoid accumulation of combustible materials;
- Planning and implementation of emergency preparedness and response plans that specifically incorporate procedures for managing uncontrolled releases of oxygen; and
- Provision of appropriate fire prevention and control equipment as described below (Fire and Explosion Hazards).

Oxygen-Deficient Atmosphere

The potential releases and accumulation of nitrogen gas into work areas can result asphyxiating conditions due to the displacement of oxygen by these gases. Prevention and control measures to reduce risks of asphyxiant gas release include:

- Design and placement of nitrogen venting systems according to recognized industry standards;
- Installation of an automatic Emergency Shutdown System that can detect and warn of the uncontrolled release of nitrogen (including the presence of oxygen deficient atmospheres in working areas[4]), initiate forced ventilation, and minimize the duration of releases; and
- Implementation of confined space entry procedures as described in the **General EHS Guidelines** with consideration of facility-specific hazards.

Chemical Hazards

Chemical exposures in natural gas processing facilities are mainly related to carbon monoxide and methanol releases. Potential inhalation exposures to chemicals emissions during routine plant operations should be managed based on the results of a job safety analysis and industrial hygiene survey and according to the occupational health and safety guidance provided in the **General EHS Guidelines.** Protection measures include worker training, work permit systems, use of personal protective equipment (PPE), and toxic gas detection systems with alarms.

Fire and Explosions

Fire and explosion hazards generated by process operations include the accidental release of Syn-gas (containing carbon monoxide and hydrogen), oxygen, and methanol. High pressure Syn-gas releases may cause "Jet Fires" or give rise to a Vapor Cloud Explosion (VCE), "Fireball," or "Flash Fire," depending on the quantity of flammable material involved and the degree of confinement of the cloud. Hydrogen, methane, and carbon monoxide gases may ignite even in the absence of ignition sources if their temperatures exceed their auto-ignition points of 500°C, 580°C, and 609°C, respectively. Flammable liquid spills may cause "Pool Fires."

3 Working areas with the potential for oxygen enriched atmospheres should be equipped with area monitoring systems capable of detecting such conditions. Workers also should be equipped with personal monitoring systems. Both types of monitoring systems should be equipped with a warning alarm set at 23.5 percent concentration of O_2 in air.

4 Working areas with the potential for oxygen deficient atmospheres should be equipped with area monitoring systems capable of detecting such conditions. Workers also should be equipped with personal monitoring systems. Both types of monitoring systems should be equipped with a warning alarm set at 19.5% concentration of O_2 in air.

Recommended measures to prevent and control fire and explosion risks from process operations include the following:

- Providing early release detection, such as pressure monitoring of gas and liquid conveyance systems, in addition to smoke and heat detection for fires;
- Limiting the inventory that may be released by isolation of the process operations in the facility from large storage inventories;
- Avoiding potential sources of ignition (e.g., by configuring the layout of piping to avoid spills over high temperature piping, equipment, and / or rotating machines);
- Controlling the potential effect of fires or explosions by segregation of process, storage, utility, and safe areas by designing, constructing, and operating them according to international standards[5] for the prevention and control of fire and explosion hazards, including provisions for distances between tanks in the facility and between the facility and adjacent buildings, provision of additional cooling water capacity for adjacent tanks, or other risk-based management approaches;[6] and
- Limiting the areas that may be potentially affected by accidental releases by:
    - Defining fire zones and equipping them with a drainage system to collect and convey accidental releases of flammable liquids to a safe containment area including secondary containment of storage tanks;
    - Installing fire / blast partition walls in areas where appropriate separation distances cannot be achieved; and
    - Designing the oily sewage system to avoid propagation of fire.

1.3 Community Health and Safety

The most significant community health and safety hazards associated with natural gas processing facilities occur during the operation phase and may include the threat from major accidents related to the aforementioned fires and explosions at the facility and potential accidental releases of raw materials or finished products during their transport outside of the processing facility. Guidance for the management of these issues is presented under the Major Hazards section below and in relevant sections of the **General EHS Guidelines** including the sections on: Traffic Safety, Transport of Hazardous Materials, and Emergency Preparedness and Response.

Additional relevant guidance applicable to the transport by sea and rail as well as shore-based facilities can be found in the EHS Guidelines for Shipping, Railways, Ports and Harbors, and Crude Oil and Petroleum Products Terminals.

[5] Further guidance to minimize exposure to static electricity and lightening is available in API Recommended Practice 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (1998).
[6] Safety distances also can be derived from industry and trade association standards, insurance providers, and specific safety analyses.

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

Tables 1 and 2 present process emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. Combustion source emissions guidelines associated with steam- and power-generation activities from sources with a capacity equal to or lower than 50 MWth are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in the use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines.** These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

Table 1. Air Emissions Levels for Natural Gas Processing Facilities[a]

Pollutant	Units	Guideline Value
NO_X	mg/Nm^3	150[b] 50[c]
SO_2	mg/Nm^3	75
Particulate Matter (PM10)	mg/Nm^3	10
VOC	mg/Nm^3	150
CO	mg/Nm^3	100

a. *Dry gas at 15% oxygen*
b. The 150 mg/NM^3 NO_X value is applicable to facilities with a total heat input capacity of up to 300 MWth.
c. The 50 mg/NM^3 NO_X value is applicable to facilities with a total heat input capacity greater than 300 MWth.

Table 2. Effluents Levels for Natural Gas Processing Facilities		
Pollutant	**Units**	**Guideline Value**
pH	--	6-9
BOD_5	mg/l	50
COD	mg/l	150
TSS	mg/l	50
Oil and Grease	mg/l	10
Cadmium	mg/l	0.1
Total Residual Chlorine	mg/l	0.2
Chromium (total)	mg/l	0.5
Copper	mg/l	0.5
Iron	mg/l	3
Zinc	mg/l	1
Cyanide **Free** **Total**	mg/l	0.1 1
Lead	mg/l	0.1
Nickel	mg/l	1.5
Heavy metals total	mg/l	5
Phenol	mg/l	0.5
Nitrogen	mg/l	40
Phosphorous	mg/l	3

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[7] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[8] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[9] Indicative Occupational Exposure Limit Values published by European Union member states,[10] or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)[11].

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals[12] as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

[7] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[8] Available at: http://www.cdc.gov/niosh/npg/
[9] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[10] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/
[11] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm
[12] Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

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Annex A: General Description of Industry Activities

For the purposes of these EHS Guidelines, natural gas processing refers to the production of liquid products from natural gas. These facilities first produce syn-gas through the Natural Gas Reforming. Syn-gas is then converted into liquid petroleum products (GTL products), which may include naphtha, gasoline, kerosene, diesel fuel, waxes, and lubes, or into methanol through methanol synthesis.

Natural gas feedstock is typically purified (e.g., de-sulfurized) and fractionated from heavy hydrocarbons in natural gas treatment facilities, as discussed in the EHS Guidelines for Oil and Gas Development (Onshore and Offshore). Natural gas processing facilities are capital-intensive operations, and are typically located in natural gas producing regions. Production capacities for GTL plants are typically in the range of 20,000 to 30,000 barrels per stream day (BPSD) of GTL products, while capacities of 50,000 to 100,000 BPSD are under evaluation. Methanol plants with a capacity of 5,000 metric tons per day (MTPD) are currently in operation, and facilities for higher production volumes (e.g., up to 7,500-10,000 MTPD), are under evaluation.

GTL Production

GTL production plants typically comprise the following process units:

- Synthetic Gas Production Unit
- Fischer-Tropsch Synthesis Unit
- Product Up-grading Unit
- Air Separation Unit (ASU)

Synthetic Gas Production Unit

Natural gas feedstock is treated to remove trace quantities of sulfur (e.g., by passing the gas over zinc oxide beds) before being fed into the Synthetic (Syn) Gas Production Unit. This unit normally consists of a reforming section followed by a heat recovery section.

The reforming section comprises a pre-reforming reactor followed by an autothermal reforming reactor. The pre-reforming reactor uses a steam reaction to convert the heavier hydrocarbons (e.g. ethane, propane) into hydrogen and carbon monoxide, to avoid the formation of soot in the autothermal reforming reactor. In the autothermal reforming reactor, methane reacts with steam and oxygen at about 950°C and 30-40 bar in the presence of a nickel-based catalyst to yield a mixture of carbon monoxide and hydrogen in the desired molar ratio.

In the heat recovery section, the reaction heat from the autothermal reforming reactor is reused to pre-heat process streams, in addition to producing high pressure steam for use in the steam turbines and to feed the pre-reforming and the autothermal reforming reactors. Cold gas leaving the heat recovery section enters a carbon dioxide removal stage, normally based on a regenerative alkaline washing, before being fed into the Fischer-Tropsch Synthesis Unit. Oxygen is provided by a dedicated Air Separation Unit (ASU), which also supplies the plant with the necessary service nitrogen.

Fischer-Tropsch Synthesis Unit

The syn-gas from the Syn-gas Production Unit then enters the Fischer-Tropsch Synthesis Unit, which principally comprises reaction, stabilization, and gas recycling sections.

In the reaction section, carbon monoxide and hydrogen react as part of the Fischer-Tropsch synthesis reaction, at about 250°C and 20-25 bar over iron or cobalt-based catalysts, to yield long-chain hydrocarbons, water, oxygenated compounds (mainly alcohols), organic acids, and minor amounts of ketones. The commercially available Fischer-Tropsch reactors include Fixed

Bed Tubular type and Fluidized Bed or Slurry type. In the stabilization section, the unconverted gas and the light-ends are separated and the unconverted gas is subsequently recycled back to the Fischer-Tropsch Synthesis Section.

The stabilized Fischer-Tropsch product enters the product up-grading unit, generally a mild hydrocracker, where under platinum or palladium catalyst, the long chain hydrocarbons are transformed into the desired end products (e.g., naphtha, gasoline, kerosene, diesel fuel, waxes, and lubes). The hydrogen necessary for the mild hydrocracker is produced by a dedicated hydrogen production process typically involving a natural gas steam reforming unit.

The utilities necessary to run the plant are mainly electric power, steam and cooling water. Nitrogen is provided by the Air Separation Unit. The plants are provided with a blow-down and a flare. These plants are normally fitted with large storage tank farms to collect the products, as well as ship loading facilities and / or pipelines to dispatch the products, similarly to refineries and other downstream petroleum facilities. More detailed information is provided in the EHS Guidelines for Crude Oil and Petroleum Product Terminals.

Methanol Production

Methanol production plants comprise Syn-gas production, methanol synthesis, and air separation units.

Syn-gas Production Unit

This unit is similar to the unit as described above for GTL plants. For capacities in excess of 5,000 MTPD, the trend is to adopt only the autothermal reformer. Existing medium-size plants with capacities up to 5,000 MTPD make use of combined reforming. The combined reforming involves a pre-reforming reactor followed by a steam reforming furnace and, finally, an autothermal reforming reactor. The pre-reforming and the autothermal reforming reactors have the same functions as described for GTL plants. In the steam reforming furnace the gas reacts with steam at about 800°C and 40-50 bar in the presence of a nickel-based catalyst.

In the heat recovery section, the reaction heat, generated in the autothermal reforming reactor, is used to pre-heat process streams and to produce high pressure steam to operate steam turbines and to feed all reforming reactors. Oxygen is again provided by a dedicated Air Separation Unit (ASU), which also supplies with the service nitrogen.

Methanol Synthesis Unit

The Methanol Synthesis Unit principally comprises reaction, gas recycle, and methanol purification sections.

In the reaction section, carbon monoxide and hydrogen react at about 250°C and 50-80 bar in the presence of a copper-based catalyst to yield methanol. The commercially available reactors are of Fixed Bed Tubular or Multi-Beds Adiabatic Radial types. Down-stream of the reactor, methanol is condensed and the unconverted gas is recycled to the Syn-gas Production Unit.

The purification section is composed of two fractionation towers where both light-ends and heavy-ends (high molecular weight alcohols) are removed from methanol product. The light-ends are normally recovered as fuel gas, while the heavy-ends are normally burned in a steam boiler with a dedicated burner. The utilities necessary to run methanol plants are the same as needed for GTL plants. The plants are provided with a blow-down and a flare, and normally include large methanol storage tanks.