EIA Guidelines for New Source Petroleum Refineries and Coal Gasification Facilities

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GLOSSARY

Alkylation: A refinery process for combining isoparafin with olefin hydrocarbons.

Area source: Source of air emissions that is relatively uniform over a large surface area, such as uncovered lagoons, storage piles, or slag heaps

Aromatic: Describes organic compounds containing at least one benzene ring

BACT: Best Available Control Technology

BDAT: Best Demonstrated Available Technology

BMP: Best Management Practices

Bituminous coal: A dark brown to black coal, also known as soft coal, which is high in carbonaceous matter and has 15-50 % volatile matter; yields significant amounts of pitch or tar.

Bottom ash: The heavier, coarser products of combustion which fall through grate at the bottom of a furnace or boiler.

Caustic: Typically refers to sodium hydroxide, but could be any other highly alkaline or alkaline-producing chemical agent added to raise pH.

Catalyst: A substance or material which alters the speed of a chemical reaction; it can be recovered virtually unchanged in form and amount after completion of the reaction.

Catalytic cracking: Cracking that involves the use of a catalyst.

Catalytic hydrocracking: A high pressure petroleum refining process in which molecules too large and complex for gasoline use have hydrogen added to them before being cracked into smaller, more suitable molecules.

CEQ: Council on Environmental Quality

Char: Also known as low-temperature coke; it is produced at temperatures ranging from 500-750 degrees Fahrenheit, and is comprised mainly of carbon and ash impurities.

Coal gasification: The conversion of coal, char, or coke to a gaseous product by reaction with air, oxygen, steam, carbon dioxide or mixtures of these.

Coking: The heating of heavy-weight petroleum distillation residuals in the absence of oxygen in order to drive off remaining volatile organics and hydrogens, yielding only the lowest boiling point organics and elemental carbon.

Cracking: The breaking of large (higher boiling point) hydrocarbon molecules into smaller (lower boiling point) ones.

DAF floats: The frothy top material containing suspended solids removed during the dissolved air flotation process.

Dissolved air flotation (DAF): A liquid-solid separation process where the main mechanism of suspended solids removal is the change in apparent specific gravity of those suspended solids in relation to the suspending liquid by attachment of small gas bubbles formed by the release of dissolved gas to the solids.

Distillation: The separation of different petroleum components by selectively heating, vaporizing and condensing compounds based on their different vapor pressures.

Dry sorbent injection: Pollution control mechanism involving the injection of finely powdered solid material into the flue gas stream upstream from particulate removal systems.

EA: Environmental Assessment

EID: Environmental Impact Document

EIS: Environmental Impact Statement

Endothermic: Describing a reaction or process which takes in energy or heat.

Entrained bed gasifier: A gasifier working on essentially powdered coal, it features the concurrent down-flow of both coal and steam-oxidant mixture, the generation of large amounts of heat, and invariably slag.

Exothermic: Describing a reaction or process which releases energy or heat.

Fluidized bed

gasifier:	In this design crushed coal that is less than one-quarter inch in diameter is introduced onto a fluidized mixture of steam, air or oxygen and coal particles at various stages of gasification.
Fly ash:	The finer particulate, products of combustion carried in the gas stream from a furnace or boiler. It may be comprised of incompletely combusted and/or non-combustible materials.
Fractionation:	A method of separation in successive stages, each stage removing a certain portion of the crude oil stream
FONSI:	Finding of No Significant Impact
GPGA:	Great Plains Gasification Association
Greenhouse effect:	Term given to the phenomenon where infrared radiation, released by the sunlight-warmed earth surface is intercepted by certain atmospheric gases; these gases act much like windows on a greenhouse.
Hazardous waste:	A hazardous waste is defined for the purposes of RCRA as one which is not specifically excluded from hazardous waste regulation, and either exhibits a hazardous characteristic (ignitability, corrosivity, reactivity or toxicity) or is specifically listed as a hazardous waste.
HRSG:	Heat recovery steam generator
HSWA:	Hazardous and Solid Waste Amendments of 1984 to RCRA
Hydrotreating:	Oil refinery catalytic process in which hydrogen is contacted with petroleum intermediate or product streams to remove impurities, such as oxygen, sulfur, nitrogen, or unsaturated hydrocarbons.
IGCC:	Integrated gasification combined cycle
Isomer:	One of two or more molecules having the same molecular weight and number and kinds of atoms, but differing in the arrangement or structure of those atoms.
Isomerization:	A process in which a compound is changed in to an isomer, for instance, in the conversion of n-butane into isobutane. In refining, a common

isomerization is the conversion of normal straight chain paraffins to branched-chain paraffins which help increase gasoline octane.

LAER: Lowest Achievable Emission Rate

Large quantity generator: A hazardous waste generator defined in RCRA as one which generates between 100 and 1,000 kg of hazardous waste per month.

Lignite: A soft coal, of relatively recent origin that is denser than peat, but not as dense as other coals.

Line source: A source of air emissions, such as a road or railroad, which can be modelled as a series of point sources.

LPG: Liquified Petroleum Gas

Medium quantity generator: A hazardous waste generator defined in RCRA as one which generates between 100 and 1,000 kg of hazardous waste per month.

Moving bed gasifier: Sometimes called a fixed bed gasifier, the design involves reacting a stationary pile of coarse-sized coal atop a grate. As the coal is gasified, the coal pile is reduced as part of the coal goes to gas, and part of the it falls through the grate as ash; thus the pile appears to slowly move downward though the grate.

MTR: Minimum Technical Standards

NAAQS: National Ambient Air Quality Standards

NEPA: National Environmental Policy Act

NESHAPS: National Emission Standards for Hazardous Air Pollutants

New Source Review: Clean Air Act required review for newly constructed facilities and expansions resulting in increased emissions. Requirements under the review are designed to prevent significant deterioration of air quality, and vary depending on whether the NAAQS have been met in the area in which the facility is located.

NMFS: National Marine Fisheries Service

Non-attainment area: An area of the country in which the concentrations of a constituent regulated under the Clean Air Act exceed the NAAQS; the area has not attained low enough concentrations.

NPDES: National Pollutant Discharge Elimination System

NSPS: New Source Performance Standards

Point source: A single, discrete source of liquid or gaseous discharge, often modelled as a point.

Polymerization: The chemical bonding of two or more identical molecules into a larger molecule.

POTW: Publicly Owned Treatment Works

RCRA: Resource Conservation and Recovery Act

Small quantity generator: A hazardous waste generator defined in RCRA as one which generates less than 100 kg of hazardous waste per month.

Slag: A glassy substance formed when ash has been heated to the point of melting and agglomeration.

Stormwater: Storm water runoff, snowmelt runoff, and surface runoff and drainage derived from precipitation.

Stripping: The coarse initial separation of petroleum compounds into higher and lower boiling point molecules.

Sub-bituminous coal: A black coal intermediate in rank between lignite and bitumious coal, having more carbon and less water than lignite.

Thermal cracking: A hydrocarbon cracking process employing heat instead of catalysts to facilitate the splitting of molecules.

Topping: Refers to distillation of crude petroleum to remove the lighter weight molecules.

TSDF: Treatment, Storage and Disposal Facility

TSS: Total Suspended Solids

SCS: U.S. Soil Conservation Service

SIPS: State Implementation Plans

SNG: Synthetic Natural Gas

SDWA: Safe Drinking Water Act

USFWS: U.S. Fish and Wildlife Service

UST: Undergound Storage Tank

VOC: Volatile Organic Compounds

Wet scrubbers: Pollution control devices that generally remove particles from flue gas by impacting them with water droplets. Such devices are typically installed in sequence with electro-static precipitators and bag-houses.

1. INTRODUCTION

The National Environmental Policy Act of 1969 (NEPA) is the basic national charter for the protection of the environment. In broad and far reaching provisions, it states the need for the United States to prevent environmental damage and ensure that decision makers in federal agencies consider the environmental consequences of their actions.

The U.S. Environmental Protection Agency (EPA) established regulations to govern its compliance with NEPA in 40 CFR Part 6. Subparts A-F of Part 6 require EPA to undertake environmental review procedures before a National Pollutant Discharge Elimination System (NPDES) discharge permit is granted for a new source. A new source can be any new facility (whether newly constructed or not) seeking a NPDES permit from EPA for which the discharge is subject to effluent limitation guidelines and standards that EPA has promulgated for specific industrial categories. Where individual states have been delegated authority to issue NPDES permits, NEPA does not apply because there is no federal decision-making on individual permits.

EPA's "Environmental Review Procedures for the New Source NPDES Program" (40 CFR Part 6, Subpart F) instructs the responsible EPA official to evaluate first if a facility is a new source and then, if it is a new source, to evaluate environmental information to determine if significant impacts are likely to occur. Some of the environmental information to be evaluated is typically provided by the NPDES permit applicant in the form of an environmental information document (EID).

To assist EPA staff and, in turn, the NPDES discharge permit applicants, EPA's Office of Federal Activities has issued a series of guidelines for EPA for use in determining the scope and contents of EIDs on new source NPDES permits for specific industries and facilities. The guidelines also assist EPA staff in reviewing and commenting on applicants' EID information. The particular industries targeted in these guidelines are new source petroleum refineries and coal gasification facilities.

An applicant's EID is used, along with EPA derived data, to evaluate if there are any significant impacts of the proposed project. If no significant impacts are anticipated, EPA issues a Finding of No Significant Impact (FONSI) for the granting of the NPDES permit. If one or more significant impacts are identified, an environmental impact statement (EIS) must be prepared by EPA.

The quality of an applicant's EID or EPA's EIS and the time it takes to develop the documents is directly related to the quality of the information requested of the applicant by EPA and, in turn, the quality of the data and analyses delivered by the applicant. Preparation of the EID provides the applicant with an opportunity to identify all the potential impacts of his project. The applicant should be working to find design modifications/siting solutions to any potential impacts identified in developing and analyzing the EID data. Project planning, feasibility, and design studies should provide the first identification of potential impacts, with the development of the EID providing a more comprehensive identification of impacts.

The project the applicant presents to EPA in the permit application and EID should reflect the applicant's best attempt to find the least environmentally damaging alternative(s), with mitigation measures for residual impacts and alternatives, if necessary. If mitigation is necessary, the applicant must present a rationale for trading off greater damages to some environmental attributes in exchange for reducing other impacts.

EPA has anticipated several audiences for these guidelines: EPA staff; NPDES discharge permit applicants and their consultants (those preparing EID information for EPA); and local, state, and foreign government environmental officials. Officials in states that have been delegated NPDES authority may find these guidelines useful in their review of individual permits. These guidelines were expressly prepared as background information for EPA staff to assist them in preparing directives to applicants and as a reference to assist in evaluating applicant/consultant prepared EIDs and EISs. All audiences should consider this document as suggestions, not as law, regulation, or policy. These guidelines replace two separate documents issued previously (EPA-130/6-81-001, EPA-130/6-80-001).

Organization of These Guidelines

These guidelines consist of three major parts:

- A regulatory overview that briefly describes NEPA, the Clean Water Act under which the NPDES permit is granted, and other relevant laws, regulations, and executive orders that provide the regulatory context for the guidelines.
- A technology overview that covers the processes and pollution control activities that are used in petroleum refining and coal gasification.
- An environmental documentation part that follows the order of a typical EIS. This part focuses on what information to ask for and to look for in new source EIDs and EISs. Emphasis is on identifying data, data assessment, methodologies, and qualitative and quantitative approaches for identifying the occurrence, magnitude, and significance of specific impacts.

2. REGULATORY OVERVIEW

This section presents information on the major federal environmental statutes. Four are covered in detail: The National Environmental Policy Act, the Clean Water Act, the Clean Air Act, and the Resource Conservation and Recovery Act. Additional statutes are briefly summarized at the end of the section.

National Environmental Policy Act

EPA's responsibility to protect the environment in the decisions it makes is governed by law,[1] regulations applied to all federal agencies,[2] and EPA's own NEPA regulations.[3] EPA's NEPA regulations specifically state that NEPA and its implementing regulations require "that Federal agencies include in their decision making processes, appropriate and careful consideration of all environmental effects of proposed actions, analyze potential environment effects of proposed actions and their alternatives for public understanding and scrutiny, avoid or minimize adverse effects of proposed actions, and restore and enhance environmental quality as much as possible." (40 CFR Part 6.100).

EPA and CEQ regulations call for the initiation of NEPA reviews as early as possible in project planning. In the specific case of petroleum refineries and coal gasification facilities, EPA must prepare environmental documentation on the NPDES permits it grants for the discharge of wastewater. The determination of a "new source" is made by the EPA Region in accordance with NPDES permit regulations under 40 CFR Parts 122.21(1) and 122.9(a) and (b). A "new source" may be defined as any facility newly constructed, or a discharge from a process or equipment that totally replaces the discharge of pollutants at an existing source, and the operator of the facility is seeking a NPDES permit from EPA for which the discharge is subject to effluent limitations guidelines for new sources. The permit applicant must provide facility and environmental data with the NPDES application, analyze environmental effects, and provide EPA with an environmental information document (EID).

In accordance with EPA NEPA procedures, the nature and extent of information required from applicants as part of the EID is bounded by two separate agreements:

- EIDS must be of sufficient scope to enable EPA to prepare its environmental assessment.

- In determining the scope of the EID, EPA must consider the size of the new source and the extent to which the applicant is capable of providing the required information. EPA must not require the applicant to gather data or perform analyses which unnecessarily duplicate either existing data or the results of existing analyses available to EPA. EPA

[1]NEPA, *42 USC* sections 4321-4370a.
[2]*40 CFR* 1500-1508.
[3]*40 CFR* Part 6.

must also keep requests for data to the minimum consistent with the Agency's responsibilities under NEPA.

The EPA procedures call for EPA to consult with the applicant to determine the scope of the EID at the outset of the process. Scoping should begin as soon as EPA is presented with the proposal.

Two other important points in the CEQ Regulations include the use of an interdisciplinary approach that insures the "... integrated use of natural and social sciences and the environmental design arts..." (40 CFR Part 1502.6) and the necessity that EISs be written in plain language so the "... decision makers and the public can readily understand them ..." (40 CFR Part 1502.8).

The NEPA Process

Once EPA has sufficient data from the applicant and other sources, a written environmental assessment (EA) is prepared that indicates whether the potential exists for significant adverse impacts from the project, and whether such impacts can be reduced to less-than-significant levels through project redesign or mitigation measures. Where significant impacts can be avoided, EPA can issue the NPDES permit, the EA, and a finding of no significant impact (FONSI).

Where environmental impacts cannot be made insignificant, an EIS must be prepared. The lead agency supervises the preparation of the EIS if more than one federal agency is involved in the same action, or the proposed action is related to activities of other agencies. When more than one agency has a direct interest in the proposed activity, the lead agency will seek the cooperation of agencies through memoranda of understanding (MOUs). The environmental analyses from the cooperating agencies are used to the maximum extent possible consistent with the responsibility of the lead agency. In the case of new source NPDES permits, EPA is the lead agency and publishes a Federal Register Notice of Intent (NOI) announcing its intention to prepare an EIS. The notice requests suggestions on the contents of the EIS. Possible alternatives, impacts, mitigation measures, and study design changes are often recommended.

For new source petroleum refineries and coal gasification facilities, EPA staff may:

- Prepare the EIS;
- Engage a knowledgeable consultant to prepare the EIS for EPA under the Agency's direction; or
- Enter into a three-party agreement where EPA directs a consulting firm in the preparation of the EIS, with the applicant funding the consultant.

Data for the EIS comes from the applicant's application, supporting materials, and EID and other sources. When a third party agreement is in effect, the applicant does not prepare an EID, but provides the same information as input to the EIS. Independent analysis or confirmation of applicant data provides EPA with reassurances that the EIS can draw supportable conclusions. EPA takes full responsibility for the scope and contents of the EIS whether it is prepared by EPA staff or a consultant.

Once the document is completed and approved by EPA, the Draft EIS is circulated for public review by the general public and other federal, state, and local agencies. Written comments on the draft EIS and those questions and comments recorded during public hearing(s) are collected by EPA and responded to by EPA staff or the EIS consultant. Information to respond to some questions or comments may require information from the applicant or reconsideration of some feature or mitigation measure of the project. The written responses to questions and comments, any minor project modification or new mitigation measures, and an incorporation by reference of the Draft EIS are collated into a Final EIS. The Final EIS is distributed to all those individuals and entities commenting on the Draft EIS.

A record of decision (ROD), a public record documenting EPA's decision-making process, is issued at the time of the NPDES permit issuance. The ROD lists any mitigation measures necessary to make the recommended alternative more environmentally acceptable. Such mitigation is made a condition of the permit.

The Clean Water Act

The primary goal of the Clean Water Act (33 U.S.C. 125 et seq.) is to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The Act covers all pollutant discharges to all waters of the United States. Permits issued under the NPDES program, Clean Water Act section 402, serve as the means to achieve this goal.

The NPDES permit program is implemented by 39 states, and where a state is not delegated authority for the program, NPDES permits are issued by the responsible EPA regional office. A NPDES Permit is required prior to the discharge of any pollutant from a point source into waters of the United States. Point sources are discharges of process water and/or stormwater runoff associated with industrial activity from any discrete conveyance including pipes, ditches, and swales.

Process Water

A NPDES permit contains specific limits on concentrations or loadings of pollutants in discharges. Pollutant discharge limits for process water are set using one or more methods. "Technology-based" limits are set using guidelines developed for particular industrial categories and their common pollutants. Discharges may also be controlled by "water quality-based" limits. Water quality-based limits are set using state ambient water quality standards and the expected dilution of pollutants in the receiving water. Limitations are developed to ensure that the concentration of a pollutant caused by a discharge would not cause an exceedance of a water quality standard in the receiving water. Water quality-based limits may be more restrictive than technology-based limits, in which case water quality-based limits are those imposed. In the absence of specific technology-specific limitations and water quality-based limitations, however, permit writers may use Best Professional Judgment (BPJ) to ensure that impacts of a discharge on receiving waters are minimized.

Application to the Petroleum Refining Industry

Petroleum refining is one of the 34 industrial categories for which technology-based effluent limitation guidelines have been established by EPA (40 CFR Part 419).

Within the effluent guidelines, EPA has set New Source Performance Standards (NSPS), Pretreatment Standards, and contaminated runoff standards for the following categories at new source petroleum refining facilities: topping, cracking, petrochemical, lube and integrated.

The NSPS apply to point sources discharging directly to waters of the United States. The Pretreatment Standards apply only to those point sources discharging to publicly-owned treatment works (POTWs), and are intended to prevent pollutants from reaching POTWs in amounts that would injure workers, pass through treatment plants, interfere with treatment processes, or contaminate sludge. The PSNS are self-implementing, and are thus enforceable even without being written into permits. Discharge limitations addressing the same pollutants covered by the PSNS may be incorporated into permits as long as they are at least as stringent as the PSNS. Stormwater guidelines define contaminated runoff as stormwater runoff contacting "any raw material, intermediate product, finished product, byproduct or waste product located on petroleum refinery property." Facilities discharging to POTWs are not subject to the NEPA process, therefore, EA/FONSI and EISs are not necessary, nor is the applicant required to submit an EID.

Application to the Coal Gasification Industry

Coal gasification is not one of the 34 industrial categories for which EPA has published specific technology-based effluent limitation guidelines. But the industry may fit (at the discretion of the state permitting agency or EPA Regional office) into one or more categories including coal preparation plants and associated areas, particularly with regard to coal pile runoff. Generally, coal gasification facilities have limited process discharges to receiving waters, and those that do occur are primarily non-contact cooling waters.

Stormwater

Stormwater runoff is regulated under the NPDES program at 40 CFR Parts 122, 123, and 124. In 1990, EPA issued regulations to address currently unpermitted discharges of stormwater associated with industrial activity. These stormwater regulations are intended to reduce or eliminate pollutants in discharges from large construction sites and industrial facilities. To ease implementation of these regulations, EPA has issued construction and industrial general permits under which eligible permittees are required to develop and implement stormwater pollution prevention plans. These plans must incorporate BMPs that control stormwater discharges and limit stormwater contact with pollutants. The stormwater regulations also allow permitting authorities to issue individual stormwater NPDES permits for discharges on a case-by-case basis.

Application to the Petroleum Refining Industry

Generally, individual permits issued to new source petroleum refineries contain effluent limits for process wastewater and stormwater discharges. In addition to the stormwater discharge limits specified for each refinery outfall, facility-specific best management practices are specified to control stormwater runoff and minimize the contact of stormwater with pollutants. Because petroleum refining facilities are subject to stormwater effluent limitation guidelines at 40 CFR Part 419, such facilities are not eligible for coverage under EPA's general permits for stormwater.

Application to the Coal Gasification Industry

Coal gasification facilities are subject to NPDES stormwater permit application requirements at 40 CFR Part 122.26(b)(14)(vii) if any gasification products are used on-site to generate power, even if only for in-plant processes.

If power is not generated at a facility, then it is regulated only if it discharges pollutants to stormwater in excess of amounts defined by EPA as Reportable Quantities. Reportable Quantities of pollutants are listed in 40 CFR Parts 117 and 302.

All regulated facilities that discharge to waters of the United States must apply for stormwater permits. Most facilities opt for coverage under EPA's general permits, as they allow permittees more flexibility in choosing BMPs than individual permits.

In addition to the requirement to implement a stormwater pollution prevention plan, general permits for coal gasification facilities have discharge limits set for total suspended solids (TSS) and pH for coal pile runoff. The limit for TSS is 50 mg/l, and pH must be no less than 6.0 and no greater than 9.0. The requirement for TSS is waived if the facility has a stormwater containment structure designed to hold runoff from a 10-year, 24-hour storm event.

Application to Construction Activity

The construction activities (including clearing, grading and excavation) involved in building either petroleum refineries or coal gasification facilities are regulated by EPA's stormwater rules if they disturb 5 or more total acres of land, a relatively small area for either type of facility. For construction sites, emphasis is placed on minimizing the erosion and sedimentation effects of stormwater runoff, in addition to minimizing contact with pollutants. Details of the pollution prevention plan requirements for construction sites, including soil stabilization practices, diversion structures, and sediment basins can be found in the Construction Permit Language and the Construction Fact Sheet of the September 9, 1992 Federal Register (Vol. 57, No. 175), and the September 15, 1992 Federal Register (Vol. 57, No. 187).

The Resource Conservation and Recovery Act

The Solid Waste Disposal Act (SWDA) of 1965 and major amendments of the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984 comprise the principal federal law mandating regulation of both solid and hazardous waste. Collectively referred to as RCRA, the law consists of three basic parts: Subtitle D, which encourages states to develop plans for controlling their *non-hazardous* solid waste, Subtitle I, which applies to underground storage tanks (USTs), and Subtitle C, which mandates a system to regulate *hazardous* wastes from the time of their generation to the time of their disposal. Because it has placed most of the burden of non-hazardous waste regulation onto the states, RCRA is now synonymous with hazardous waste regulation. Once a waste is determined to be hazardous, any generator, transporter or manager of such waste must comply with the pertinent rules promulgated under Subtitle C.

A waste is regulated as hazardous if:

- It is not specifically excluded from regulation as a hazardous waste (40 CFR Part 261.4)

AND

- Exhibits one of the hazardous characteristics detailed in 40 CFR Part 261 Subpart C (ignitability, corrosivity, reactivity, or toxicity)

OR

- Is specifically listed as a hazardous waste (40 CFR Part 261, Subpart D).

The wastes excluded from regulation typically include wastes recycled in certain ways, wastes regulated under separate statutes (such as the Clean Water Act), and particular wastes from certain industries.

Non-hazardous Waste Requirements - Subtitle D

Subtitle D's provisions include minimum standards for protecting human health and the environment at solid waste landfills and technical guidance for states on establishing environmentally-sound solid waste management plans. The specific regulatory controls on non-hazardous waste depend on the requirements of state plans. For questions concerning non-hazardous waste regulation in a particular state, a copy of the state's solid waste management plan should be consulted.

Underground Storage Tank Requirements - Subtitle I

RCRA's requirements for underground storage tank systems apply to systems of 110-gallon capacity or greater. The requirements include controls on the design, construction, and installation of new underground storage tanks, and the upgrading of existing tanks. Provisions cover general operating requirements as well as the detection, reporting, investigation, and confirmation of releases. The regulations also address release response and corrective action requirements for petroleum and hazardous substance-containing USTs at 40 CFR Parts 280.60 - 280.67. In general, the extensive costs and liabilities of operating an UST in compliance with RCRA requirements have led to significant reductions in the number of new UST units and removal from service of many older tanks. RCRA does not include similar requirements for above ground tanks.

Hazardous Waste Requirements - Subtitle C

The hazardous waste regulations provide for a comprehensive "cradle to grave" system of management and include rules governing waste disposed of on land, recycling, and generators, and transport, storage, or disposal facilities (TSDFs). The applicability of these regulations is generally uniform across industry, and is driven by the listing process. If a waste is hazardous, it is subject to these regulations. Some industries, like petroleum refining, have specific wastes listed as hazardous; others, such as coal gasification may have specific wastes listed as non-hazardous.

Land Disposal Restrictions

The Hazardous and Solid Waste Amendments (HSWA) of 1984 (40 CFR Part 268) prohibits the land disposal of any hazardous waste that does not meet certain treatment standards. Treatment standards may be concentration-based (the most common) or technology-based (use of the best demonstrated available technology [BDAT]). HSWA automatically prohibits the land disposal of hazardous wastes if EPA fails to establish treatment standards for them by certain statutory deadlines (see 40 CFR Parts 268.10 - 268.12). Wastes may be excluded from these land disposal restrictions (LDR) under circumstances described at 40 CFR Part 268.1(c).

Recycling and Reuse Exemptions and Provisions

Under 40 CFR Part 261.2(e), certain recyclable materials are exempt from hazardous waste regulation if they qualify as one of the following:

- Wastes used or reused as ingredients in production without first being reclaimed
- Wastes used or reused as substitutes for commercial products without first being reclaimed
- Wastes returned to the original process that generated them without first being reclaimed.

RCRA also contains standards at 40 CFR Part 266 concerning the land application of recyclable materials derived from hazardous waste, the burning of hazardous waste for energy recovery, and the burning of hazardous waste in boilers and industrial furnaces.

Hazardous Waste Generators

All generators of waste are required to determine if the waste is hazardous and, in most cases, determine the amount generated in each calendar month. Requirements for generators vary according to the amount of waste produced, with small quantity generators subject to the least stringent controls.

Medium and large quantity generators are facilities that generate between 100 - 1,000 kg and greater than 1,000 kg of hazardous waste per month, respectively. They have similar types of requirements, although some requirements are more strict for large quantity generators.

Medium and large quantity generators having waste transported off-site must certify that they have a waste minimization program in place to reduce the amount and/or toxicity of the hazardous waste generated prior shipment to a transport, storage, or disposal facility (TSDF).

Medium and large quantity generators may accumulate hazardous waste on site without obtaining a TSDF permit provided they comply with the regulations regarding quantity limits, time constraints, and technical storage standards for on-site accumulation, and requirements for personnel training, emergency procedures, and preparedness and prevention of accidents and spills (see 40 CFR Part 262.34).

Hazardous Waste Treatment, Storage, and Disposal Facilities

As with transporters, hazardous waste management facilities must obtain a permit before beginning operations. Under such permits, TSDFs must comply with the following requirements:

- General waste handling requirements — personnel training, waste analysis prior to management, location standards (fault zones and flood plains)
- Preparedness and Prevention
- Contingency plans and emergency procedures.

Ground Water Monitoring

In addition to the TSDF requirements outlined above, HSWA of 1984 added certain minimum technical requirements (MTRs) for the construction of hazardous waste management facilities. All new facilities completed after HSWA's enactment must have, at a minimum, double liners and leachate detection and control systems in place. Retrofitting of most facilities existing at the time of HSWA's enactment was to have been finished in 1988. Any waste exempt from the land disposal restrictions of HSWA must still go to a MTR-equipped facility for its disposal or management.

Under Parts 264 and 265, RCRA also specifies more detailed operating parameters for the following:[4]

container storage units
tank systems
land treatment
incinerators
landfills
drip pads
surface impoundments
waste piles
underground injection wells
thermal treatment units
chemical, physical, biological treatment units

Application to the Petroleum Refining Industry

While the majority of RCRA's hazardous waste regulations apply generally to all facilities and wastes, certain provisions and controls address specific industries. Several listed hazardous wastes are from petroleum refining operations. Several other hazardous wastes listed from non-specific sources could also be generated by petroleum refineries. Listed wastes from refineries include the following:[5]

- K048 - Dissolved air flotation (DAF) floats
- K049 - Slop oil emulsion solids
- K050 - Heat exchanger bundle cleaning sludge
- K051 - API separator sludge
- K052 - Tank bottoms (leaded).

Hazardous wastes from non-specific sources, potentially from petroleum refineries, include the following:[6]

- F024 - Process wastes[7]
- F025 - Condensed light ends, spent filters and filter aids, and spent desiccant wastes[7]
- F037 - Primary oil/water/solids separation sludge
- F038 - Secondary (emulsified) oil/water/solids separation sludge
- F039 - Leachate resulting from disposal of more than one hazardous waste.

Many organic chemical wastes may be generated by petroleum refineries. Wastes not excluded at 40 CFR Part 261.4 may still be hazardous if they exhibit a hazardous characteristic.

[4]Standards for these processes are specified only for interim status facilities (40 CFR Part 265).
[5]These wastes are defined under the petroleum refinery sub-category of Part 261.32 (the K list).
[6]These wastes are defined at 40 CFR Part 261.31 (the F list).
[7]From the production of certain chlorinated aliphatic compounds by free radical catalyzed processes.

Application to the Coal Gasification Industry

The coal gasification industry is not addressed specifically by rules promulgated under RCRA. However, certain wastes that are generated at coal gasification facilities are excluded from coverage under hazardous waste regulations. Fly ash waste, bottom ash waste, slag waste, and flue gas emission control waste are all exempt from regulation if they are derived from the combustion of coal or other fossil fuel. Other coal gasification wastes may be ruled hazardous if they are specifically listed or exhibit one of the four hazardous characteristics.

For further guidance on the specifics and applicability of RCRA, consult:

Wagner, Travis, P., *The Complete Guide to the Hazardous Waste Regulations*, Second edition, Van Nostrand Reinhold, New York, New York, 1991.

The Clean Air Act

The Clean Air Act, originally passed in 1967, and amended as recently as November 1990, is the primary law protecting the Nation's air quality from pollutant emissions. The Act requires EPA to promulgate a set of air quality standards, whose achievement is the overall objective of the Act. These National Ambient Air Quality Standards (NAAQS) were established for ozone, carbon monoxide, particulates, sulfur dioxide, nitrogen dioxide, and lead. To achieve these standards, the Act requires states to develop State Implementation Plans (SIPs) which combine region-specific compliance strategies with enforceable emissions control requirements.

While the November 15, 1990 amendments make significant changes to the Clean Air Act, these changes are to be phased in over a number of years. Because of this transition period, it is necessary to describe the Act as it stands now, as well as new provisions and when they will take effect.

Current Clean Air Act Requirements

There are three major existing requirements under the Clean Air Act. These are New Source Reviews, New Source Performance Standards, and National Emissions Standards for Hazardous Air Pollutants. Each of these is explained briefly below.

New Source Review

Newly constructed industrial facilities and expansions of existing facilities that result in increased emissions are subject to a New Source Review. The requirements of this review vary depending on whether or not air quality standards have been attained in the area the site is located.

In areas already meeting air quality standards, rules are designed to prevent new sources from preventing significant deterioration (PSD) of air quality. The general requirements under these circumstances are:

- Compliance is necessary only for new major sources (potential emissions of any regulated pollutant exceeding either 100 or 250 tons per year, depending on the source's industrial category) and major modifications to such sources (defined as 40 tons per year for sulfur dioxide [SO_2], nitrogen oxides [NO_x], or volatile organic compounds [VOCs]).

- Construction of new sources cannot begin until a permit has been issued.

- Best Available Control Technology (BACT) must be used. BACT is identified by EPA on a case-by-case basis as the best state-of-the-art control technology that could be used. The applicant must justify any departures from this technology.

- After BACT requirements are satisfied, any residual emissions must be accounted for by an available "increment" of air quality deterioration.

The restrictions are more severe in areas that have not attained the ambient air quality standards. These requirements are outlined below:

- Compliance is necessary only for new major sources (potential emissions exceeding 100 tons per year of particulates, SO_2, NO_x, VOCs, or carbon monoxide [CO]) and major modifications.

- Lowest Achievable Emission Rate technology (LAER) must be used. This technology must be the most stringent control technology available.

- Any residual emissions after installation of LAER must be "offset" by emissions reductions at other sources which must exceed the reductions expected from the application of LAER technology.

PSD and non-attainment requirements are applied to each regulated pollutant separately. It is thus possible for a new source to be required to meet non-attainment "offset" requirements for one pollutant, while having to meet PSD "increment" requirements for another.

New Source Performance Standards (NSPS)

Emissions limitations have been established for certain pollutants from new sources. Under the current regulations, sources subject only to NSPS are not necessarily required to obtain a permit. However, the NSPSs are self-implementing, meaning new sources are automatically subject to their requirements.

The performance standards for new source petroleum refineries address the following areas (40 CFR Part 60, subpart J):

- Particulate matter and carbon monoxide from fluid catalytic cracking unit catalyst regenerators
- Sulfur oxides.

Coal gasification is not an industrial category for which EPA has established NSPS. Coal gasification facilities which generate steam from the combustion of coal do have NSPS as fossil-fuel-fired steam generators. The performance standards for this category address particulate matter, sulfur dioxide and nitrogen oxides.

National Emissions Standards for Hazardous Air Pollutants (NESHAPs)

The 1970 Clean Air Act authorized EPA to set special standards for hazardous air pollutants. EPA has established NESHAPs for 7 substances: arsenic, asbestos, benzene, beryllium, mercury, radionuclides, and vinyl chloride (see 40 CFR Part 61).

Changes to Take Effect as 1990 Amendments Are Phased in

Several new or more stringent requirements will come into effect as the 1990 Amendments to the Clean Air Act are implemented. The most significant changes relate to a new federal-level permit program and overhaul of the air toxics program. New provisions are described briefly below.

Federal Permit Program

The new Amendments place much greater emphasis on federal control than the current SIP-dependent Act. They require virtually all significant sources of air emissions to obtain permits. SIP requirements are often applied generically, permitting an array of industrial operations to take place as long as appropriate pollution controls are installed. The permit program will be much more specific, defining applicable emissions limits for each individual source. Any operational change that increases emissions above specified limits will probably necessitate permit modifications.

New Source Review

Smaller sources and modifications will become subject to New Source Review requirements. A change causing <u>any</u> increase in emissions will be considered a modification in extreme non-attainment areas, and 25 tons per year will be considered a major source in serious and severe non-attainment areas.

Non-attainment Offsets

In an effort to reduce the number and severity of ozone non-attainment areas, the ratio between the residual emissions still escaping after LAER technology is installed and the decrease in emissions elsewhere required to offset them will be significantly increased for VOCs. In addition, NO_x will generally be subject to offset requirements.

New Source Performance Standards (NSPS)

Permits will be required for all new sources that are subject only to NSPS. Permits must be obtained before any construction can begin.

NESHAPS

The air toxics program has been completely redone. There is now a list of 189 hazardous air pollutants that are to be regulated. The strategy of regulation has been changed from a substance-specific numerical approach, to one relying on the use of Maximum Achievable Control Technology (MACT).

Other Relevant Requirements

There are several acts and executive orders that are significant in the review of NEPA documentation. The provisions of the most important acts are outlined below.

Clean Water Act Section 404 Permits

Clean Water Act Section 404 requires a permit from the U.S. Army Corps of Engineers (USCOE) for the placement of material, whether dredged or fill, into waters of the US. The 404 permit also pertains to activities in wetlands and riparian areas. Before being issued a Section 404 permit, an applicant must obtain a Clean Water Act Section 401 certification from the EPA (or the state agency delegated NPDES Authority), which states that any discharge complies with all applicable effluent limitations and water quality standards. Exemptions to Section 404 are listed in Section 404(r) which refers to federal projects specifically authorized by Congress if information on the effects of such discharge is included in an EIS.

If the state in which the new source coal gasification or petroleum refining facility is to be built has been delegated 404 permit authority, then, as with the NPDES Program, the issuance of the 404 permit is not a federal action, and is not subject to NEPA requirements. If the state has neither NPDES nor 404 permit authority, then the issuance of both types of permits is done by a federal agency and is thus subject to environmental review under NEPA. In this instance, CEQ regulations at 40 CFR 1501.5 require that a lead agency by designated to conduct a single environmental review associated with the issuance of all permits for the facility. Regardless which agency is leading the review, neither the NPDES permit nor the 404 permit may be issued before the review process is completed and its results (either a FONSI or a final EIS) published in the Federal Register.

Endangered Species Act

Established in 1973, the Endangered Species Act (16 U.S.C. 1531-1544; P.L. 93-205) provides a means whereby the ecosystems supporting threatened or endangered species may be conserved and provides a program for the conservation of such species. The Act requires that all federal departments and agencies seek to conserve endangered and threatened species and cooperate with state and local agencies to resolve water resource issues in concert with conservation of endangered species.

Section 7 of this Act requires federal agencies to ensure that all federally associated activities within the United States do not have adverse impacts on the continued existence of threatened or endangered species or on designated areas (critical habitats) that are important in conserving those species. Agencies undertaking a federal action must consult with the U.S. Fish and Wildlife Service (USFWS), which maintains current lists of species that have been designated as threatened or endangered, to determine the potential impacts a project may have on protected species. The National Marine Fisheries Service undertakes the consultation function for marine and anadromous fish species while USFWS is responsible for terrestrial, wetland, and fresh water species.

The USFWS has established a system of informal and formal consultation procedures, and the results of informal or formal consultations with the USFWS under Section 7 of the Act should be described and documented in the EID/EIS. Sections of an EID/EIS that should include endangered and threatened species information are the Project Alternatives and the Affected Environment sections. If a threatened or endangered species may be located within the project area and may be affected by the project, a detailed endangered species assessment (Biological Assessment) may be prepared independently or concurrently with the EIS and included as an appendix to the EID/EIS.

National Historic Preservation Act

The National Historic Preservation Act of 1966 (16 U.S.C. 470 *et seq.*, P.L. 89-665) as amended (P.L. 95-515) establishes federal programs to further the efforts of private agencies and individuals in preserving the historical and cultural foundations of the nation. This Act authorizes the establishment of the National Register of Historical Places. It establishes an Advisory Council on Historic Preservation authorized to review and comment upon activities licensed by the federal government that have an effect upon sites listed on the National Register of Historic Places or that are eligible to be listed. The Act also sets up a National Trust Fund to administer grants for historic preservation. The Act also authorizes regulations addressing State historical preservation programs. State preservation programs can be approved where they meet minimum specified criteria. Additionally, Native American tribes may assume the functions of State Historical Preservation Officers over tribal lands where the tribes meet minimum requirements.

Under the Act, federal agencies assume the responsibility for preserving historical properties owned or controlled by the agencies.

Section 106 of the NHPA requires that every federal agency "take into account" how each of its undertakings could affect historic properties. Historic properties are any properties included or eligible for listing in the National Register of Historic Places. The issuance of a NPDES permit constitutes an "undertaking" under the Act. When an undertaking affects an historic property, comments of the Advisory Council regarding the action must be sought. The federal agency involved is responsible for initiating and completing the Section 106 review process.

A series of amendments to the National Historic Preservation Act in 1980 contain codification of portions of Executive Order 11593 (Protection and Enhancement of the Cultural Environment - 16 USC 470). These amendments require an inventory of federal resources and federal agency programs to protect historic resources and authorize federal agencies to charge federal permittees and licensees reasonable costs for protection activities.

Where activities involve a proposed federal action or federally assisted undertaking, or require a license from a federal or independent agency, and such activities affect any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register, the agency or licenses must afford the Advisory Council on Historic Preservation a reasonable opportunity to comment with regard to the undertaking. Such agencies or licensees are also obligated to consult with State and Native American Historic Preservation Officers responsible for implementing approved State programs.

It should be noted that regulations codified at 40 CFR Part 6.605(b)(4) provide that issuance of a new source NPDES permit that will have "significant direct and adverse effect on a property listed in or eligible for listing in the National Register of Historic Places" triggers the preparation of an EIS.

Coastal Zone Management Act

The Coastal Zone Management Act's (15 CFR 930, P.L. 92-583) purpose is "to preserve, protect, develop, and where possible, restore or enhance, the resources of the Nation's coastal zone for this and future generations." To perform this goal, the Act provides for financial and technical assistance and federal guidance to states and territories for the conservation and management of coastal resources.

States are encouraged, but not required, by the Act to develop a coastal zone management program considering such things as ecological, cultural, historic, and aesthetic values as well as economic development needs. Section 307(c) of the Act prohibits the USEPA from issuing a permit for any activity affecting land or water use in the coastal zone until the applicant certifies that the proposed activity complies with the state Coastal Zone Management program, and the state or its designated agency concurs with the certification.

Executive Orders 11988 and 11990

Executive Order 11988 (Floodplain Management) of 1977 requires each federal agency to "... avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative..." within the 100-year flood elevation. For an EID/EIS, this requires that alternatives to avoid development in a floodplain be considered. If development requires siting in a floodplain, action shall be taken to modify or design the facility in a way to avoid damage by floods.

Executive Order 11990 (Protection of Wetlands) of 1977 is similar to E.O. 11988 in that it requires each federal agency to "...avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative..." When constructing a new facility, actions that minimize the destruction, loss, or degradation of wetlands, and actions to preserve and enhance the natural and beneficial values of wetlands are required. If there is no practicable alternative to wetland construction projects, proposed action must include measures to minimize harm. Construction in wetlands also falls under Section 404 of the Clean Water Act administered by the U.S. Army Corps of Engineers.

Executive Order 12898 (Environmental Justice)

During the past decade, it has become apparent that environmental impacts do not affect all people equally. Studies by the U.S. General Accounting Office, the United Church of Christ, community leaders, and academics has brought attention to the inequitable exposure to environmental hazards that some ethnic and lower income communities face.[8] In recognition of environmental justice issues and for fair treatment for all socio-economic classes, the President directed each federal agency in Executive Order 12898 to "develop an agency-wide environmental justice strategy . . . that identifies and addresses disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

Due to its requirements for social impact analysis and public participation, NEPA can be used by federal agencies to integrate the principles of environmental justice into agency missions and actions. The greatest level of legal vulnerability for the "lead agency" is created not by taking actions that will create negative impacts, but by failing to consider or possibly analyze those impacts in an EIS that treats them with full, good-faith consideration. While the term

[8] U.S. General Accounting Office, *Siting of Hazardous Waste Landfills and Their Correlation with Racial and Economic Status of Surrounding Communities*. GAO/RCED-83-168, June 1, 1983. Commission for Racial Justice, United Church of Christ, *Toxic Waste and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites*, New York, 1987. Holmes Ralston III, *Environmental Ethics*, Temple University Press: Philadelphia, PA 1988. Peter S. Wenz, *Environmental Justice*, State of New York Press: Albany, NY, 1988.

"environmental justice" has not been formally defined, the general principle is for all segments of the population, whatever race, ethnicity, or income, be treated fairly with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Farmland Protection Policy Act

Under the Farmland Protection Policy Act of 1980 (P.L. 97-98), the U.S. Soil Conservation Service (SCS) is required to be contacted and asked to identify whether a proposed facility will affect any lands classified as prime and unique farmlands.

Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 401-413; 33 CFR 322) prohibits the unauthorized obstruction or alteration of any navigable waters of the United States. Under Section 10 of this Act, a permit is required from the U.S. Army Corps of Engineers for the construction of any structure in or over navigable waters of the United States. Section 10 is usually combined with Section 404 of the Clean Water Act, which covers the discharges of fill to all waters of the United States (as opposed to Section 10, which covers only navigable waters).

Wild and Scenic Rivers Act

The Wild and Scenic Rivers Act of 1968 (P.L. 90-542, 16 U.S.C. 1273 *et seq.)* ensures that "... Certain selected rivers...shall be preserved in a free flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." The Act, in Section 7, prohibits the issuance of a license for construction of any water resources project that would have a direct, adverse effect (stop free-flowing conditions or affect their local environments) on the rivers of the United States selected as possessing remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values.

The National Rivers Inventory has selected rivers and streams placed by acts of Congress, while other rivers and streams have been proposed to be included in the inventory. During project planning and project impacts identification for an EID/EIS, these rivers and streams must be considered and the findings should be noted in a Wild and Scenic Rivers Act summary. While there is no legal requirement to consider state-listed wild and scenic rivers and streams or unique areas during project planning or in an EID/EIS, it is recommended that any impacts to such areas be considered and addressed as with the federal Wild and Scenic Rivers Act requirements.

Fish and Wildlife Coordination Act

Enacted in 1934, the Fish and Wildlife Coordination Act (16 U.S.C. 661 *et seq.*, P.L. 85-624) authorizes the Secretary of Interior to provide assistance to, and cooperate with, federal, state, and public or private agencies and organizations in the development, protection, rearing, and stocking of all species of wildlife, resources thereof, and their habitat. The majority of the Act is associated with the coordination of wildlife conservation and other features of water-resource development programs. The EID/EIS should include a Fish and Wildlife Coordination Act report which includes all coordination efforts in the planning process of the project with the Act, and recommendations of the USFWS must be summarized in the EID/EIS, usually as part of the Consultation and Coordination section.

3. TECHNOLOGY OVERVIEW

Petroleum Refining

Petroleum refining is the processing of crude oil into a multitude of products. Crude oil characteristics vary with their sources, and refineries are often designed to process only crude oil from a particular source. Refineries also differ widely in capacity and in the combination of processes and products produced. Some may be able to produce a wide range of items such as fuel gas, liquified petroleum gases (LPG), gasoline, olefins, greases, asphalt, and coke. Other simpler refinery operations may produce only fuel gas, gasoline blending stocks, or heavy fuel oil.

In general, refinery crude oil processing is based on the fact that crude oil consists of a large number of separate organic compounds whose properties are primarily dependent on the number of carbon atoms they contain. Increasing numbers of carbon atoms result in higher boiling points, and the first step in the refining process is to separate the crude by distillation into several fractions according to boiling point. The lowest temperature boiling fraction, a gas at normal conditions, consists of methane, having a single carbon atom, and other molecules ranging from 2 to 4 carbon atoms. These components of the first, or gas, fraction are used as fuel gas, LPG (mainly propane and butane), and as building blocks in petrochemical processes. The next higher-boiling fractions, called naphtha and kerosene, are used in the production of gasolines and jet fuels and contain components in a range centering around 7 carbon atoms. The next higher-boiling fraction, middle distillates, is the stock from which diesel and light fuel oils are made. The still higher boiling fractions become the heavier fuel oils and lubricating oils.

While some of these initial fractions may be satisfactory as final products (e.g., heavy fuel oil), most require additional processing such as further separation, solvent finishing, or reforming in the presence of a catalyst. Additional processing such as cracking, conversion, or reconstruction may be required. In these processes, the fractions are converted to salable products by cracking (i.e., splitting the molecules into smaller carbon compounds) then rearranging the molecular structure. Middle distillate and fuel oil fractions are often processed to break them up into smaller components (cracking) to increase the yield of gasolines and other light products. The heavy residues can be used directly as residual fuel oils, or processed to give lighter fractions.

Typically Used Processes

There are five basic processes that are common to many refineries. These include desalting (removing salt from the crude oil), distillation and fractionation (separating different organic fractions from the raw crude), cracking (breaking down large carbon molecules into smaller ones), reconstruction (changing the form of the molecule), and treating (purifying various fractions for end uses). These are shown schematically in Figure 1 and are discussed briefly below.

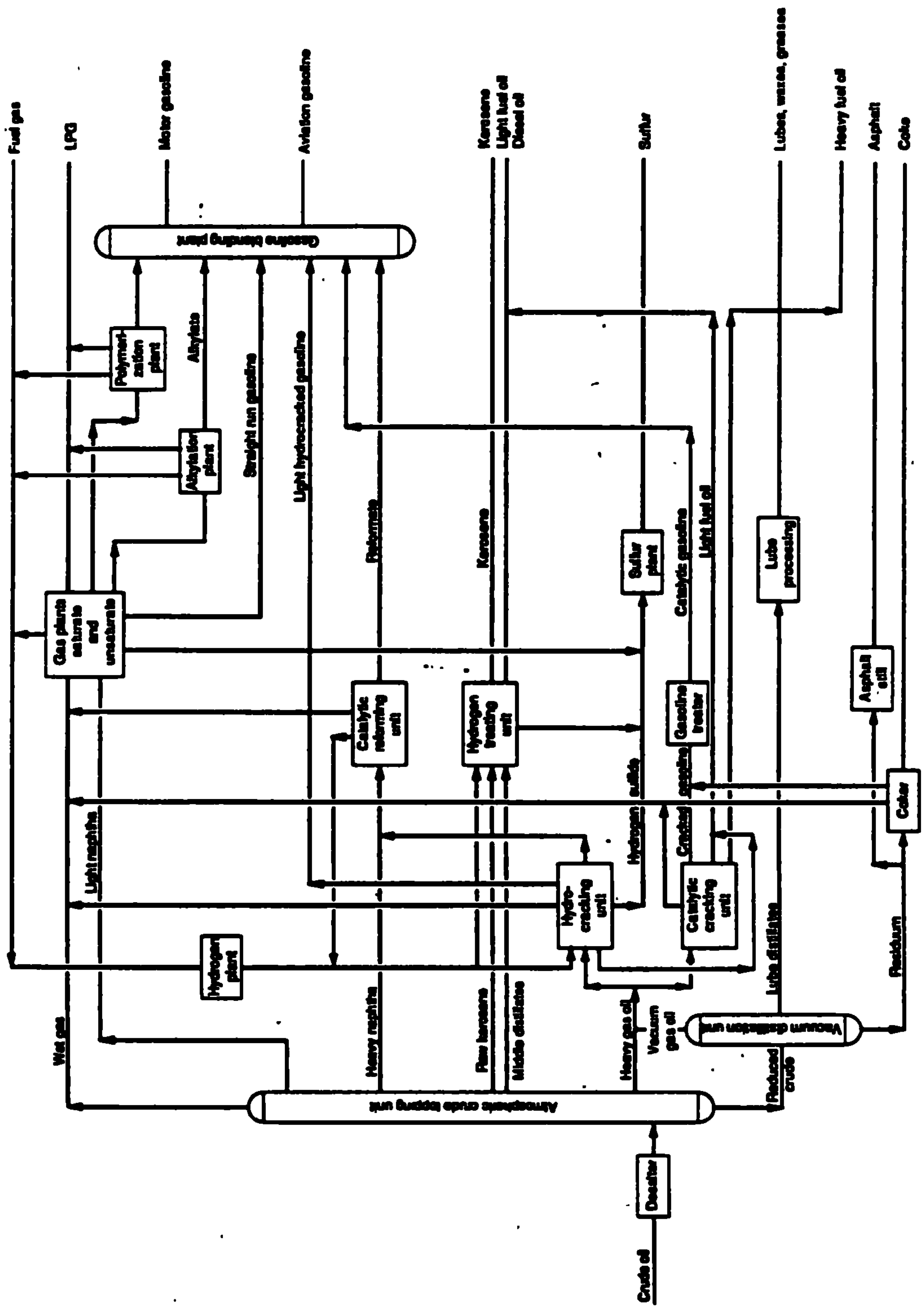

FIGURE 1. CONFIGURATION OF TYPICAL INTEGRATED PETROLEUM REFINERY

Desalting

Brine is typically produced with crude oil. Salt concentrations in brine vary from almost zero to hundreds of kilograms of sodium chloride (NaCl) per 1,000 barrels (bbl). To extract the salts, the crude is processed through a desalter. The desalter is usually upstream of the distillation unit so that corrosion of equipment is minimized. The removed salts become part of the refinery waste stream.

Salts are removed as brines in settling towers, usually at elevated temperatures (90 - 145 °C; 200 - 300 °F) and pressures (3.4 - 17 atmospheres; 50 - 250 pounds per square inch [psi]). The towers are packed with sand, gravel, or excelsior. Caustic is sometimes added to adjust pH. In some cases, an electrical field (16,500 - 33,000 volts) is applied across the vessel to cause droplets to coalesce more rapidly. Chemicals (such as modified fatty acids, partly or wholly saponified with ammonia; oil-soluble petroleum sulfonate; water-soluble solvents; oil-soluble solvents or inorganic sulfates) are used to improve the efficiency of the desalting process.

Distillation and Fractionation

The crude oil is composed of a variety of carbon compounds. Typically, there are lighter carbon chains that may be volatilized and removed from the crude stream. Distillation is a method of separation by which a gas or vapor from the liquid crude is generated by applying heat in a process vessel. The gases and vapors are collected and condensed into liquids.

"Topping" refers to the distillation of crude petroleum to remove the light fractions only. Typically, the crude distillation unit in a refinery is called the "topping unit."

Fractionation is a method of separation in successive stages, each stage removing some proportion of a component from the crude stream, as by distillation, or by differential solubility in water-solvent mixtures. Crude oil is fractionated by distilling at the lowest boiling point, collecting the distillate as one fraction, then collecting the next fraction as the component with the next highest boiling point begins to distill. The fractions are then processed in other refinery units to make specific products.

A typical topping unit will resolve the crude into the following fractions:

By distillation at atmospheric pressure:

- A light, straight-run fraction (gasoline blending stock), primarily consisting of the C_5 and C_6 hydrocarbons, but also containing some C_4 and lighter hydrocarbons, which are routed to a central gas-concentration unit for further resolution. The stabilized C_5/C_6 blend usually contains odorous mercaptans, which normally are treated for odor improvement before delivery to the refinery gasoline pool.
- A naphtha (kerosene) fraction having a nominal boiling range of 93 - 204 °C (200 - 400 °F).

- A light fuel oil distillate with boiling range of 204 - 343 °C (400 - 650 °F).

By vacuum flashing:

- Heavy fuel oil having a boiling range of 343 - 566 °C (650 - 1,050 °F)
- A nondistillable residual pitch.

Cracking

Cracking is the breaking up of large carbon chain molecules to make shorter ones. This is done to increase the gasoline fraction of the final products.

Catalytic Cracking

Catalytic cracking is the conversion of high-boiling hydrocarbons into lower-boiling types by reacting in the presence of a catalyst. A distilled gas-oil stream is fed at elevated temperatures from 460 - 515 °C (860 - 955 °F) to a vessel containing a catalyst bed (usually silica-alumina) in which the compounds are converted to simpler hydrocarbons, usually of a higher octane number. Light olefin is usually produced as a byproduct. The catalyst arrangement employed (fixed bed, fluid bed, multiple bed, single bed, etc.) varies, but the catalyst is always regenerated until it is spent. The spent catalyst is a unique waste stream which may, in some cases, be a hazardous waste.

The primary function of catalytic cracking is to convert into gasoline those fractions having boiling ranges higher than that of gasoline. After treatment for odor control, the produced fractions are blended with other gasoline stocks. An important secondary function is to create light olefins such as propylene and butylenes to be used as feedstocks for motor-fuel alkylation and petrochemical production. Although the principal feedstock is the gas oil separated from the crude by distillation, this feed is often supplemented with light distillates and with distillate fractions resulting from thermal coking operations.

For practical reasons, the cracking of distillate feedstock to lighter materials is not carried to completion. The remaining, uncracked distillates (cycle oils) are usually used as components for domestic heating fuels (generally after hydrotreating) and are blended with residual fractions to reduce their viscosity to make heavy fuel oil. In some refineries, however, cycle oils are hydrocracked to complete their conversion to gasoline.

The principal products then, are gasolines, whose unleaded octane numbers range from 89 to 93, and light olefins. Another product is isobutane, a necessary reactant for the alkylation process.

Catalytic Hydrocracking

In a sense, hydrocracking is complementary and supplementary to catalytic cracking because hydrocracking occurs over a catalyst in a hydrogen environment with heavy distillates and, in some cases, with cycle oils which are impractical to convert completely in catalytic cracking units. The purpose of hydrocracking is to produce additional gasoline stock from heavy materials. The process also takes place at lower temperatures and higher pressures than fluid catalytic cracking. Generally, the C_5-C_6 fraction is blended into the gasoline pool, and occasionally the heavier portion of the gasoline is also blended into the gasoline pool although the primary products are gasoline or jet fuels and other light distillates. An important secondary product is isobutane. Sometimes this portion is reformed first, to improve its octane number. Figure 1 shows only heavy gas oil as a feedstock, and in the figure, the entire liquid product as gasoline is routed directly to the refinery gasoline pool even though the processes described above are performed widely in various combinations.

Thermal Cracking

The heavy fractions, as produced by most vacuum-flashing units, are too viscous to be marketed as a heavy fuel oil without further treatment. In some refineries, the pitch processing in a thermal cracking unit (visbreaking) at relatively low temperatures and short contact times reduces viscosity sufficiently. Additional viscosity reduction is obtained by blending in catalytically produced oil to produce marketable residual fuel oil.

In certain situations it is more economical to process the pitch in a thermal coking unit resulting in gasoline, distillates, and coke. The gasoline from a coking unit is handled as previously described. The coke can be used, after calcination, for electrode manufacture when it meets certain purity specifications, but the coke is used principally as a metallurgical coke or fuel. Distillates from thermal coking operations may be used as feedstock for catalytic cracking or the lighter distillates may be routed to the refinery distillate produce pool for hydrotreatment.

A few refiners obtain additional feedstock for catalytic cracking or hydrocracking operations by solvent extraction of the vacuum pitch, usually with propane as the solvent. The extract is relatively free of organometallic compounds and highly condensed aromatic hydrocarbons which are difficult to crack. Thus, the extract is suitable for handling by catalytic units. Extracted pitch is processed subsequently in thermal units or converted to asphalts.

The small amount of thermal gasoline that is made as a byproduct is routed after treatment to the gasoline pool or to catalytic reforming through a hydrotreating unit because its octane number is relatively low.

Reconstruction

Reforming is the rearranging, in the presence of a catalyst, of hydrocarbon molecules in a gasoline boiling-range feedstock to form hydrocarbons having a higher antiknock quality.

In order to raise the octane rating of the heavy naphtha fraction (Figure 1) (which varies with the crude source, normally ranging from 40 to 50) so that it will be a suitable component for blending into finished gasoline pools, the chemical composition of the fraction must be changed. This is usually accomplished by catalytic reforming.

It should be noted that practically all naphtha stocks fed to catalytic reforming units are hydrotreated to remove or inactivate arsenic, sulfur, and nitrogen compounds that would deactivate the catalyst. The resulting naphtha, called reformate, is then fed into the gasoline blending pool. Byproducts of this process include hydrogen that is used in hydrotreating or hydrocracking. Reforming of natural gas or light naphtha fractions with steam also produces hydrogen.

Hydrotreating

As a processing tool, hydrotreating has numerous applications in a refinery. Its principal function is to saturate olefins and convert oxygen, sulfur, and nitrogen to compounds that can be removed. It also converts other impurities such as arsenic to more easily removable compounds. The process employs hydrogen and a catalyst. The use of hydrotreating for pretreating naphthas prior to catalytic reforming has been already mentioned.

Figure 1 shows hydrotreatment of the crude light distillate (kerosine middle distillate) and the catalytic cycle oil in a single block before being routed to the refinery light distillate pool. Occasionally the light distillate in the crude may be sufficiently low in sulfur content to bypass hydrotreating; usually, however, part of the stream must be hydrotreated to remove native sulfur compounds. Some refineries hydrotreat parts of their catalytic cracking feeds, particularly if they originate from thermal operations or if they are inordinately high in sulfur content.

Desulfurization is also an objective in the production of low sulfur residual fuel oils. Sulfur content of reduced crudes (> 4 %) can be reduced to about 1 % by vacuum flashing, hydrodesulfurizing the overhead vacuum-distilled gas oil and blending the gas oil of low sulfur content with the untreated pitch to obtain a reconstituted low-sulfur fuel oil.

Alkylation

In motor fuel refineries, the alkylation units produce a high quality paraffinic gasoline by the chemical combination of isobutane with propylene and/or butylenes. A small amount of pentenes is also alkylated. The alkylation is accomplished with the catalytic aid of hydrofluoric acid (HF) or sulfuric acid (H_2SO_4) to produce a gasoline with unleaded octane numbers that range from 93 to 95.

Propane and n-butane associated with the olefins in the feedstocks are withdrawn from alkylation units as byproducts. Part of the n-butane is routed to the gasoline pool to adjust the vapor pressure of the gasoline to a level permitting prompt and easy starting of engines. The remainder of the n-butane and the propane is available for LPG, a clean fuel that is easily distributed as bottled gas for heating purposes.

Polymerization

Polymerization involves the combination of small molecules (i.e., ethylene) into somewhat larger compounds (C_6 and higher) including cyclic compounds such as benzene and toluene.

Polymerization is usually carried out thermally in the vapor phase at 510 - 595 °C (950 - 1,100 °F) for extended periods of time. Reaction pressures are about 170 atmospheres (2,500 psi) with a yield of 62 - 72 % by weight.

Catalytic polymerization is carried out in the presence of phosphoric acid or other catalysts (silica-alumina, aluminum chloride, boron trifluoride and activated bauxite). Phosphoric acid is used in three forms (quartz wetted with liquid acid, acid-impregnated pellets, or solid catalyst pellets) packed in tubes surrounded with cooling water. This process operates at pressures of 17 - 60 atmospheres (250 - 900 psi) and temperatures of 155 - 230 °C (310 - 450 °F).

Isomerization

In this process, normal paraffins are converted to branched chain paraffins in order to produce higher octane gasoline. Aluminum chloride is the principal catalyst used for this purpose. Temperatures range from 80 - 130°C (180 - 270 °F) with pressures of 13 - 20 atmospheres (200 psi).

Reforming

Reforming is a process in which a variety of complex and cyclic hydrocarbons are converted to hydrocarbons to produce better gasoline and does so with a much lower use of catalysts.

Platinum and molybdenum are used to produce the following changes:

- Naphthalene dehydrogenation (removal of hydrogen)
- Naphthalene dehydroisomerization (removal of hydrogen and isomerization)
- Paraffin dehydrocyclization (removal of hydrogen and oxygenation of paraffins)
- Paraffin isomerization
- Paraffin hydropacking
- Olefin hydrogenation (addition of hydrogen to unsaturates)
- Hydrodesulfurization (addition of hydrogen and elimination of sulfur).

Treating

Gas Concentration

The gas concentration system collects gaseous product streams from various processing units and physically separates the components to provide, usually, a C_3/C_4 stream as a feedstock for alkylation and a C_2 and lighter stream that is used to supply process heat (requirements) for the refinery.

Hydrogen sulfide is removed from gas streams where it occurs by selective absorption in liquid solutions (usually organic amines). The H_2S released from the rich solution is converted by further processing into elemental sulfur or H_2SO_4 (sulfuric acid).

Coking

Coking is a process in which contact times are lengthened in a thermal cracker so that polymerization or condensation products are produced. However, only the most degraded carbonaceous high-boiling parts of the cracking reaction are exposed. Coking takes place at temperatures over 435 °C (820 °F). The main purpose of coking is the production of coker gas oil which is charged to catalytic or thermal crackers. In addition, coke is heated in kilns at 590 - 650 °C (1,100 - 1,200 °F) to produce artificial graphite.

The coking process has been found to be a promising method of recycling some refinery wastes, such as tank bottoms and other heavy, oily sludges.

Asphalt Production

Asphalt is produced by vacuum flashing of hot cracked tar as part of the cracking operation or from the steam distillation of various stages. The quality of asphalt can be improved by air blowing with the use of ferric chloride or phosphorous cutoxide. Heavy topped crude oil or vacuum reduced residue is heated to within 30 °C (50 °F.) of its flash point and blown with 1 - 1.6 cu. $m^3 min^{-1}$ per metric ton (30 - 50 cu. ft./minute of air/ton of asphalt) over a period of 1.5 to 2.4 hours.

Lube Oil Production

Reduced oxide is taken to a vacuum fractionator where gas oil is removed. The various fractions other than the residual is sent to solvent extraction where various solvents (i.e., phenol, furfural) are used to recover the lube oil fraction. This is then sent to a solvent dewaxing unit where propane or methyl ethyl ketone is used to remove wax. The produce is heated with clay to remove acidity.

Current Trends

The kinds of petroleum refineries that will be built depend on a number of factors affecting the types of petroleum products required, the location of crude supplies and markets for final products, and the regulatory environment. The following sections discuss current trends in each of these areas.

Supply and Demand

Trends in the supply and demand of petroleum products are a function of a several factors including changes in national economic health and regulatory requirements, weather severity (extreme heat or cold), and events such as hurricanes and floods. The only predictable trends, however, are caused by changes in the state of the economy and regulatory changes. Increased economic activity during 1992, for example, spurred growth in vehicle miles traveled. This, combined with a slowed increase in fleet-wide fuel efficiency, resulted in greater gasoline demand. The improving economy also spurred a growth in industrial production, causing increased demand for distillate fuel oil. If the recovery from the economic slump of the early 1990s continues, demand for gasoline and distillate fuel oil can be expected to increase accordingly. Both motor gasoline and distillate fuel oil are already in the highest demand of all the major U.S. refinery products.

Historically, the most predictable supply and demand changes have been due to changes in regulatory control. Demand for residual fuel oil has been on a steady decline for some years now because its relatively high sulfur content results in higher, expensive-to-control sulfur dioxide emissions. This decline is expected to continue as residual fuel oil is replaced by cleaner fuels.

The cleaner fuels requirements of the 1990 Clean Air Act Amendments (CAAA) are already causing significant changes in the demand for motor gasoline oxygenates and their precursors. As of November 1, 1992, all 41 cities that exceeded the national air quality standard for carbon monoxide in 1988 and 1989 had to use gasoline containing more oxygen (average of 2.7 % by weight) for at least the four winter months. Requirements will tighten further on January 1, 1995, when reformulated gasoline, containing at least 2 wt % oxygen and reduced amounts of benzene and aromatics must be supplied year round in the 9 worst non-attainment areas for ozone. As of May 1992, nine additional states had requested inclusion in this reformulated gasoline program, and other states were considering doing the same. In addition to the EPA program, California will require the use of reformulated gasoline year-round for all areas beginning in 1996.

Because of these developments, U.S. demand for oxygenates (e.g. methyl tertiary butyl ether [MTBE] and ethanol) is expected to rise to at least 411,000 barrels per day (bpd), and possibly much higher, depending on how many additional areas opt to be included in the EPA program. Even though U.S. oxygenate production capacity is expected to more than double from its April 1992 level of 236,000 bpd of MTBE equivalents, it may not be able to satisfy domestic demand. Supply shortfall could reach almost 250,000 bpd in winter months if all 96 ozone non-attainment areas are included in EPA's program.

Demand for oxygenate precursors like butane and methanol can be expected to increase proportionally with that of oxygenates. While domestic production of such precursors is expected to rise, it is not expected to satisfy demand. Part of the reason for this is that some refiners are unwilling to pay the high cost of construction and environmental permits associated with increasing production capacity. EPA may waive reformulated gasoline requirements in some areas in the event of supply shortages, but that is by no means certain. It is likely that imports of finished reformulated gasoline, and oxygenates and their precursors will have to cover much of the shortfall. Non-North American oxygenate production capacity is expected to increase by approximately 300 % by the mid-1990s.

Alternative-fuel vehicle requirements under the CAAA will increase demand for non-gasoline power sources. Alcohol-based fuels and liquified petroleum gases are two of the more prominent alternative fuels. Demand for propane is expected to rise significantly due to an additional one million new propane-fueled vehicles estimated to be purchased by government and commercial light truck and bus fleets.

Configuration and Production Levels

Recent trends in operable crude refinery capacity and production have been varied. During 1992 the number of operable refineries in the United States shrank from 199 to 187, resulting in a year end capacity of 15.5 million bpd. This 1.6 percent drop was due to the shutting down of 13 refineries as a result of more stringent product requirements and a poor economy. Only three new refineries came on line in 1992.

Refinery inputs and production have been increasing because decreases in refinery capacity have been offset by the activation of idle capacity. Corresponding to demand increases, production of both motor gasoline and distillate fuel oil has been rising. As with the demand for these products, if the national economy continues to improve, production of finished gasoline and distillate fuel oil should increase as well. Production of residual fuel oil, on the other hand, is declining. This trend can be expected to continue as long as demand for this product declines.

Geographic Distribution

There are a number of trends and patterns in the location of refineries and where certain products are produced. Refineries are typically located near coastlines, for ease of transportation of crudes by ship. Some refineries are located inland, closer to oil fields where crude is produced. The products are then transported by pipeline or truck to distribution.

The majority of U.S. refinery capacity lies within the Gulf Coast, Midwest and West Coast states, accounting for 44.7 percent, 22.5 percent and 19.2 percent of national capacity respectively. East Coast and Rocky Mountain states account for only 10.2 and 3.4 percent of national capacity, respectively.

Gasoline oxygenates are produced mostly in the Midwest and Gulf Coast regions. Ethanol, derived from corn, is produced almost entirely in the agriculturally rich Midwest (94 % of total ethanol production). The Gulf Coast produces the vast majority of all other oxygenates, including 84 percent of all MTBE and 86 percent of all methanol produced.

Raw Materials

In general, there has been a proportional increase in the use of imported crudes from Africa, the Middle East, and North and South America. Production of domestic crude has been decreasing due to low prices and high costs.

U.S. refiners processed slightly more than 4.9 billion barrels of crude in 1992. Slightly over half of this was domestically produced, with about one fifth coming from Alaska. Other major domestic sources were Texas and the Gulf Coast, and California. Most of the imported crude came from only a few countries: Saudi Arabia was the dominant U.S. crude supplier, accounting for roughly one fourth all imports. Venezuela and Canada together also supplied roughly one fourth of U.S. refinery inputs, with Venezuela's contribution having increased dramatically over the last couple years. Other key sources included Mexico, Nigeria, and Angola.

Refiners on the East Coast used 96 percent imported oil in 1992, with Nigeria and Angola supplying 41 percent of this, and Saudi Arabia, Venezuela, Mexico and Canada supplying most of the rest. Midwest refiners processed roughly 60 percent domestic crudes in 1992. Virtually all of the domestic supply came from the lower 48 states. Canada supplied roughly half of Midwest imported refinery inputs, with most of the remaining imports coming from Saudi Arabia, Venezuela, Mexico and Nigeria.

Slightly less than half of Gulf Coast area crude inputs were from domestic sources, and almost all of this was from the lower 48 states. Saudi Arabia, Mexico, and Venezuela accounted for 70 percent of Gulf area imported inputs, with Nigeria, Angola, and Great Britain also being major sources. The Rocky Mountain region refineries used just over 80 percent domestic oil during 1992, all of it from outside of Alaska. Canada supplied their imported crudes. West Coast states refined over 90 percent domestic oil in 1992, with 61 percent of that coming from Alaska. West Coast imported crude inputs came mostly from Indonesia, Ecuador, and Canada.

Pollution Prevention

In general, there is a trend toward increasing environmental regulation, including more stringent control of effluents and emissions, and reduction of allowable contaminant limits in effluents and emissions. As laws become more stringent, traditional end-of-pipe treatment methods are becoming economically unattractive.

In addition, the Pollution Prevention Act of 1990 specified a hierarchical national pollution prevention policy that de-emphasizes waste treatment and disposal. The policy states that waste should be reduced at the source through process and product modification and material substitution whenever feasible. Wastes should be recycled back into processes, beneficially reused, or utilized for materials recovery as a second tier. Waste disposal should be considered only as a last resort. Because of these factors, refineries will be looking toward more waste minimization and pollution prevention-oriented approaches for dealing with their wastes.

There will be major changes in the design of new refineries resulting in numerous equipment improvements and process modifications to increase efficiency and reduce the amounts of pollution and solid waste generated. Many articles and studies have been published recently in refinery-related literature describing cost-effective, efficient new technologies and strategies for minimizing waste and preventing or dealing with pollution. According to a recent API document on environmental design considerations, more sophisticated process controls are available to optimize refinery energy consumption, and thus minimize furnace and boiler emissions for any fuel used. There may also be a trend toward the use of more accurate pollutant detection instruments, such as energy absorption probes. Use of these probes has already enabled some refiners to cheaply increase oil/water separation efficiencies, thereby greatly reducing the amount of oil escaping to individual waste streams before they ever reach the WWTP (HP 8/93).

Trends in toxics control in refinery wastewater are such that emphasis will be placed on source control, as exotic tertiary treatment is expensive and contaminant-selective. Attention will be paid to the resulting effluent quality and source processes in treatment system design phases. The reduction of toxics will require further data gathering to understand toxicity sources more clearly and identify cost-effective solutions. More efficient water use and recycling are bound to be attractive options (Frayne, 1992---HP 8/92).

In general, refinery trends in emissions reduction will focus on those pollutants subject to tighter controls, such as VOCs and oxides of nitrogen. In an effort by refiners to reduce fugitive VOC emissions, new refineries will need to employ specialized hardware (e.g., better valves, pumps, flanges, and vents) and better operation and maintenance procedures (API, 1993). Benzene emissions from refinery wastewater can be greatly reduced by stripping the benzene from oil desalter brine before sending the brine to the treatment plant. The stripped benzene can then be reused in blending gasoline. Nitrogen oxide emissions can be reduced by installing new low-NO_x burners and selective catalytic reduction of flue gases.

Trends in waste management are to reduce the volumes and toxicity of wastes, partly to meet new regulations, but also to reduce costs of disposal of hazardous waste. BDAT-qualifying pretreatment methods such as tank-based biological treatment will have to be used. Tank-based and other totally enclosed treatment systems may be selected as they are often exempted from expensive RCRA permits. As on-site treatment standards become more stringent, there may also be a trend toward separate treatment of concentrated, individual waste streams, as this is often more cost-effective.

Coal Gasification

Prior to World II, there were more than 1,000 plants making gas from coal in the United States to provide street lighting. During this time, coal gasification technologies improved greatly. However, the availability of electric power and natural gas virtually eliminated coal gasification as a source of fuel gas for domestic lighting or heating.

There were two periods in the 1970s when shortages of liquid transportation fuels developed because of reduced crude oil production in the Middle East. The United States, being a major consumer and importer of liquid transportation fuels, was especially hard hit. As a consequence, the United States Synthetic Fuels Corporation (US SFC) was founded to foster development of liquid transportation fuels and other gaseous fuels from solid fossil fuels. The Department of Energy (DOE) and its predecessor, the Energy Research and Development Agency (ERDA), was also involved in this effort, initiating a very large coal gasification project in North Dakota for the production of synthetic natural gas (SNG).

Both the SFC and DOE leaned toward coal gasification projects because their products and processes were environmentally benign, and because U.S. reserves of coal and lignite are very large. Although the US SFC was abolished in the 1980s, the DOE continues to promote coal gasification. Furthermore, as the electric power industry's current facilities in the United States become obsolete, and as environmental restrictions on new power-generating sources become more severe, coal gasification facilities should begin to replace conventional coal-burning facilities.

Process Overview

Coal gasification is a process in which coal is converted non catalytically to a gaseous fuel through partial oxidation. All grades of coal — anthracite, bituminous coal, subbituminous coal, lignite, and even peat — are amenable to coal gasification, but generally only bituminous and subbituminous coals and lignite are used. The resulting gaseous fuel is subjected to various purification steps to remove suspended solid particulate matter, and acid gases (primarily hydrogen sulfide [H_2S], carbonyl sulfide [COS], and CO_2). Removal of these constituents is desirable and necessary to make the fuel more environmentally acceptable.

When a fuel is burned, its potential chemical energy is converted to heat, and this can then be converted to mechanical or electrical power. When oxygen available from the air combines with the carbon (C) and hydrogen (H or H_2), the common products of combustion, along with heat, are carbon dioxide (CO_2) and water vapor (H_2O). Both of these products are fully oxidized and cannot be oxidized further. However, if the available supply of oxygen is decreased, other products, such as carbon monoxide (CO), hydrogen, and methane (CH_4), are formed. All of these products are gaseous, can be readily and inexpensively transported, and can be burned for energy release at another place.

The chemistry of coal gasification is complex. The principal reactions are as follows:

Exothermic reactions that give off heat

Carbon combustion:

$$C + O_2 = CO_2 \qquad (1)$$

$$C + 1/2\ O_2 = CO \qquad (2)$$

Water-gas shift:

$$CO + H_2O = CO_2 + H_2 \qquad (3)$$

Methanation:

$$CO + 3\ H_2 = CH_4 + H_2O \qquad (4)$$

$$C + 2\ H_2 = CH_4 \qquad (5)$$

Endothermic reactions that absorb heat

Boudouard reaction:

$$C + CO_2 = 2\ CO \qquad (6)$$

Steam-carbon reaction:

$$C + H_20 = CO + H_2 \qquad (7)$$

Hydrogen liberation:

$$2\ H\ (\text{in coal}) = H_2\ (\text{gas}) \qquad (8)$$

Although some reactions release heat and others absorb heat, the net result is autothermic — sufficient heat is released and sufficiently high temperatures generated so that both types of reactions take place simultaneously.

There are two main reaction stages that occur in gasification: devolatization and char gasification. The first stage, devolatization, begins to occur as soon as coal enters a hot gasifier. The organic matrix in the coal breaks down to form hydrocarbon gases, oils and tars, and phenols. Depending on gasifier configuration, residence time, and reactor temperature, these materials may pass out of the reactor or may be further reacted to CO, CO_2, H_2O, and H_2. After volatilization, a substance called "char" remains. Char is composed primarily of ash and carbon, and generally most of the carbon is reacted to form gaseous products. Depending on reactor configuration, coal characteristics, and operating temperatures, the residual from combustion of char is removed from the reactor as an ash or a molten slag. Fused ash, in a molten state, is known as slag, which solidifies upon cooling.

Typical Configurations

Although there are numerous coal gasification processes, they are generally of three major types based on reactor design: moving bed gasifier, fluidized bed gasifier, and entrained flow gasifier. These are described briefly below.

Moving Bed Gasifiers

In this design (sometimes also referred to as a fixed-bed gasifier), coal is introduced at the top of a reactor onto a grate. Steam and air (or oxygen) are introduced at the bottom of the reactor, and pass upward through the grate and the bed of coal. As the coal is consumed by reacting with steam and oxygen, it forms ash or slag, which falls through the grate and is removed at the bottom of the reactor. Thus, the bed of coal appears to move slowly toward the grate.

When coal is first introduced to the reactor at the top of the column, it loses moisture and is heated. With continued heating, it descends and begins to volatilize. Some of the volatile matter reacts to produce a fuel gas, but some leaves the reactor and is recovered downstream. In the last stage, coal has descended almost to the grate and only char remains. The char reacts with the incoming steam and oxygen to form fuel gas, and residual ash or slag falls through the grate and is removed from the reactor. Total residence time of the coal and its solid intermediates in the reactor is about 30-60 minutes.

Fluidized Bed Gasifiers

In this design, crushed coal particles are introduced into a dicrate fluidized bed of coal where the particles are in various stages of gasification. The fluidizing gas is a mixture of steam and oxygen (or air). The reaction must be maintained below ash fusion temperatures in order to avoid formation of clinkers (large agglomerates of molten, fused ash particles, or slag) that would affect the behavior of the fluidized bed. Conversely, an agglomerate fluidized bed provides a hot zone where ash particles can be agglomerated to a controlled size prior to removal from the fluidized bed.

Entrained Flow Gasifiers

This type of gasifier features concurrent down-flow of both coal and steam-plus-oxidant. It can handle most grades of coal and it features a high level of heat generation in a short reaction period. Because of the high temperatures involved, the process always results in slag formation rather than ash.

A more detailed breakdown of gasifier characteristics is presented in Table 1.

TABLE 1. GASIFIER CHARACTERISTICS

	Moving Bed	
Ash Conditions:	**Dry Ash**	**Slagging**
Feed coal characteristics:		
Size	Coarse (< 2 inches)	Coarse (< 2 inches)
Acceptability of fines	Limited	Better than dry ash
Acceptability of caking coal	Yes (with modifications)	Yes (with modifications)
Preferred coal rank	Low	High
Operating characteristics:		
Exit gas temperature	Low (800 to 1200°F)	Low (800 to 1200°F)
Oxidant requirement	Low	Low
Steam requirement	High	Low
Key distinguishing characteristics	Hydrocarbon liquids in the raw gas	
Key technical issue	Utilization of fines and hydrocarbon liquids	
	Fluidized Bed	
Ash Conditions:	**Dry Ash**	**Agglomerating**
Feed coal characteristics:		
Size	Crushed (<0.25 inches)	Crushed (<0.25 inches)
Acceptability of fines	Good	Better
Acceptability of caking coal	Possibly	Yes
Preferred coal rank	Low	Any
Operating characteristics:		
Exit gas temperature	Moderate (1700 to 1900 °F)	Moderate (1700 to 1900 °F)
Oxidant requirement	Moderate	Moderate
Steam requirement	Moderate	Moderate
Key distinguishing characteristics	Large char recycle	
Key technical issue	Carbon conversion	
	Entrained Flow	
Ash Conditions:	**Dry Ash**	
Feed coal characteristics:		
Size	Pulverized (<100 mesh)	
Acceptability of fines	Unlimited	
Acceptability of caking coal	Yes	
Preferred coal rank	Any	
Operating characteristics:		
Exit gas temperature	High (>2300°F)	
Oxidant requirement	High	
Steam requirement	Low	
Key distinguishing characteristics	Large amount of sensible heat energy in the hot raw gas	
Key technical issue	Ras gas cooling	

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Major Products

In addition to categorizing coal gasifiers by reactor design, they can also be classified by products created (final products are always the result of additional reaction steps subsequent to gasification). In broad terms, coal gasifiers are operated in order to:

- Produce a low BTU fuel gas for use in generating electrical energy, steam, or a combination of both
- Produce gaseous hydrogen for subsequent manufacture of ammonia or for use in hydrogenation operations in petroleum refineries
- Produce gaseous chemical intermediates which can be used to produce synthetic natural gas (SNG) or chemicals such as methanol or acetic acid.

Each of these is described below.

Fuel Gas

There are three major types of operations generating fuel gas in the United States: for electric power generation, hydrogen generation, or synthetic natural gas production. Each of these is described briefly below.

Electric Power

Construction of coal gasifiers in the United States is primarily directed toward production of low BTU gases (160 - 350 BTU/standard cubic foot [sfc]) for combustion in "integrated gasification combined cycle" (IGCC) facilities. In such facilities, coal is partially oxidized with air or oxygen, and after cleaning, the gas is burned in a gas turbine to produce electrical power. The hot exhaust gases from the turbine are then directed to a "heat recovery steam generator" (HRSG) to produce high pressure steam that is then discharged through a steam turbine to produce additional power. If steam is also needed for other purposes, it can be removed from the HRSG. The practice of producing electrical power from both hot gases and steam, plus diverting some steam for process use, is termed "cogeneration."

Hydrogen

The practice of gasifying coal to furnish the energy required to produce hydrogen from water is used in many locations in the world. The primary uses for the hydrogen are as raw material for the commercial production of ammonia and, to a lesser extent, for hydrogenation of petroleum stocks.

Synthetic Natural Gas (SNG) and Chemicals

The production of gaseous chemical intermediates for producing organic chemicals and liquid fuels is also practiced in many parts of the world. Most of the liquid fuels used in South Africa are based on conversion of gases produced from low-grade coal. In the United States, the Tennessee-Eastman Company, in Kingsport, TN, produces methanol, acetic acid, and other organic chemicals from gases produced by a Texaco coal gasifier. In Beulah, ND, a very large facility based on the Lurgi coal gasification technology uses about 22,000 tons per day of lignite to produce about 138 million sfc of pipeline-quality SNG. Other, but minor products include phenol and ammonia. A facility of this type could also produce methanol, and in turn, gasoline from the methanol.

Typical Processes

There are no standard or typical processes in use for coal gasification. The best appreciation for the range of processes currently in use is gained by understanding some of the range of technologies presently employed. A few of the more significant technologies are presented in Table 2. A sampling of projects is described below.

Coal Gasification

There are several coal gasification projects in the United States that have been successfully operated for up to 9 years. There are also five full-scale coal gasification demonstration projects that are supported by the DOE and are either in the planning and design stage, or are in construction. Some of these existing and planned projects are discussed in the following paragraphs to develop the breadth of designs, technologies, products, and uses that are encompassed by coal gasification technologies and gas cleaning processes.

Combustion Engineering IGCC Repowering Project

This project will be located at the Springfield, IL, City Water, Light and Power's Lakeside Station, and will demonstrate Combustion Engineering's dry feed, air blown, two-stage, entrained-flow coal gasifier with a moving-bed zinc titanate, hot gas cleanup system. The following description of the project and process is taken from a DOE document (DOE/FE-0272).

> "Six hundred tons per day of pressurized pulverized coal is pneumatically transported to the gasifier. The gasifier essentially consists of a bottom combustor section and a top reductor section. Coal is fed into both sections. A slag tap at the bottom of the combustor allows molten slag to flow into a water-filled quench tank."

> "The raw, low-BTU gas 100-150 BTU/scf (HHV) and char leave the gasifier at approximately 2,000 °F and are reduced in temperature to about 1,000 °F in a heat exchanger. Char in the gas stream is captured by a high-efficiency cyclone, as well as by

TABLE 2. PARTIAL LIST OF GASIFICATION TECHNOLOGIES

Technology	Type	U.S. Vendor or Owner
Texaco Gasification Power Systems	Entrained flow, oxygen blown	Texaco Development Corporation, Texaco Inc., White Plains, NY
Shell Coal Gasification Processes	Entrained flow	Synfuels Business Development, Shell Oil Company, Houston, TX
Noelle Gasification Technology	Entrained flow, oxygen blown	Noelle Inc., Herndon, VA
KRW Gasifier	Pressurized fluidized bed, air blown	M.W. Kellogg Company, Houston, TX
Destec Coal Gasifier	Entrained flow, oxygen blown	Destec Energy, Inc., Houston, TX
MCTI Pulse Combustion Process	Fluidized bed, steam blown	Manufacturing and Technology Conversion International, Inc., Columbia, MD
Tampella U-Gas Gasification System	Fluidized bed, air blown	Institute of Gas Technology, Chicago, IL
Lurgi Coal Pressure Gasification Process	Moving bed, oxygen blown	Lurgi Corporation, Paramus, NJ
British Gas/Lurgi Coal Gasifier	Moving bed, oxygen blown	Lurgi Corporation, Paramus, NJ
Lurgi Circulating Fluid Bed Gasifier	Fluidized bed, air or oxygen blown	Lurgi Corporation, Paramus, NJ
High Temperature Winkler Gasification Process	Fluidized bed, air or oxygen blown	Lurgi Corporation, Paramus, NJ
Combustion Engineering Coal Gasification Process	Entrained flow, air blown	ABB Combustion Engineering Systems, Windsor, CT

a subsequent fine-particulate removal system, and recycled back to the gasifier."

"A newly developed process consisting of a moving bed of zinc titanate sorbent is being used to remove sulfur from the hot gas. Particulate emissions are removed from the coal-handling system and gas stream by a combination of cyclone separators and baghouses, and a high percentage of particulates are fed back to the gasifier for more complete reaction and ultimate removal with the slag."

The cleaned low-BTU gas is routed to a combined-cycle system for electric power production. About 40 megawatts (MW) are generated by a gas turbine. The gas turbine is used to provide the high-pressure air requirements of the gasifier and the zinc titanate desulfurization system. Exhaust gases from the gas turbine are used to produce steam which is fed to a bottoming cycle to generate an additional 25 MW for a total of 65 MW.

The anticipated heat rate for the repowered unit is 8,800 BTU/kilowatt hour (an efficiency of 38.8 %), and SO_2 emissions are expected to be less than 0.1 lb/million BTU (99 % removal). NO_x emissions are also expected to be less than 0.1 lb/million BTU (90 % removal).

Figure 2 presents the essential details of the gasifier and its process train.

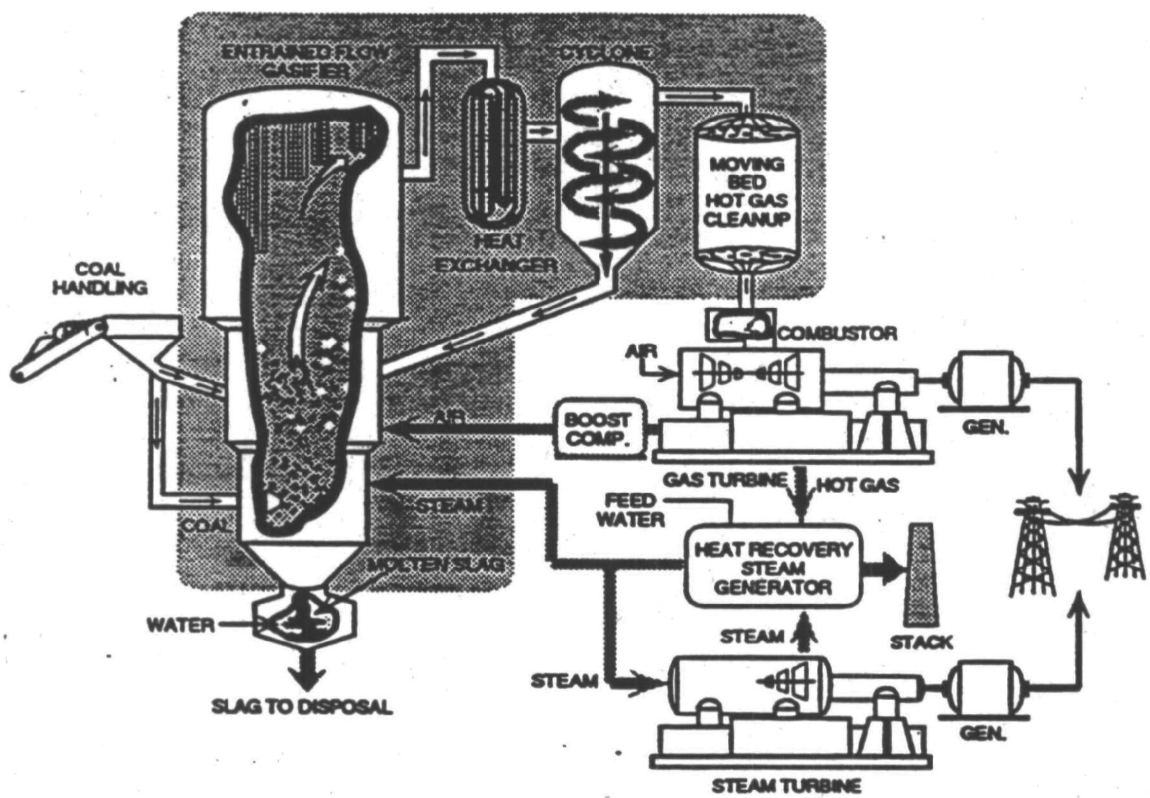

FIGURE 2. SCHEMATIC FLOW CHART OF COMBUSTION ENGINEERING'S IGCC PROJECT IN SPRINGFIELD, ILLINOIS

Some of the salient features of this project are:

- The oxidant for coal is air so no auxiliary oxygen plant is required. Compared to facilities requiring an oxygen plant, capital and operating costs are lessened since internal use of electric power to operate the oxygen is not needed. On the other hand, the product gas has a very low BTU value compared to oxygen-blown gasifiers.
- All types of coal can be processed.
- No tars or oils are produced, and char is recycled. Carbon loss is therefore negligible.
- Additional heat economies are also achieved through the hot gas cleanup. Systems that require crude gas cooling prior to cleanup and require reheat prior to combustion result in a loss in overall thermal efficiency.

Lurgi Gasification/Great Plains Coal Gasification Project

The Great Plains Gasification Association (GPGA) coal gasification plant, located in Beulah, ND, is one of the few commercial-scale synthetic fuels facilities in the United States and was the Nation's first commercial-scale coal gasification project to become operational.

The GPGA plant is massive, as indicated by the following statistics. The lignite raw material handled is 22,000 tons per day (tpd), of which 14,000 tpd are input to the gasification process (the coal fines balance is used by the adjacent Basin Electric power plant.) The plant's design capacity is 137.5 million standard cubic feet per day (scfd) of high-BTU pipeline-quality synthetic natural gas (SNG), with a nominal production level of 125 million scfd (equivalent to 20,000 barrels of oil). The plant occupies about one-half of a 1,127-acre site, not including the adjacent electric power station or the nearby coal mining and ash disposal areas.

SNG production at the GPGA facility involves the following process steps:

- Coal preparation and handling
- Gasification and lock gas recovery
- Shift conversion
- Gas cooling
- Acid-gas and naphtha removal (Rectisol)
- Methanation
- Product gas drying and compression.

The heart of the gasification plant is the gasifier building containing fourteen Lurgi Mark 4 gasifiers. Twelve gasifiers are sufficient to achieve design capacity. The additional two gasifiers are spares allowing for continuous overhaul without reducing the plant output. Each gasifier is about 14 feet in diameter and 40 feet tall. Lignite is fed through a lock hopper system into a gasifier operating at a pressure of 430 psi. Steam and oxygen, mixed and introduced into the gasifier from the bottom, are distributed upward through the coal bed by a rotating grate.

As lignite descends through the four zones in the gasifier (drying, carbonization, gasification and combustion zones), it is reduced to ash while producing the raw gas.

The overall process requires the following auxiliary unit operations:

- Oxygen plant
- Methanol synthesis
- Steam generation
- Sulfur recovery (Stretford)
- Phosam NH_3 recovery
- Phenosolvan phenols recovery.

A simplified flow diagram of the process is shown in Figure 3.

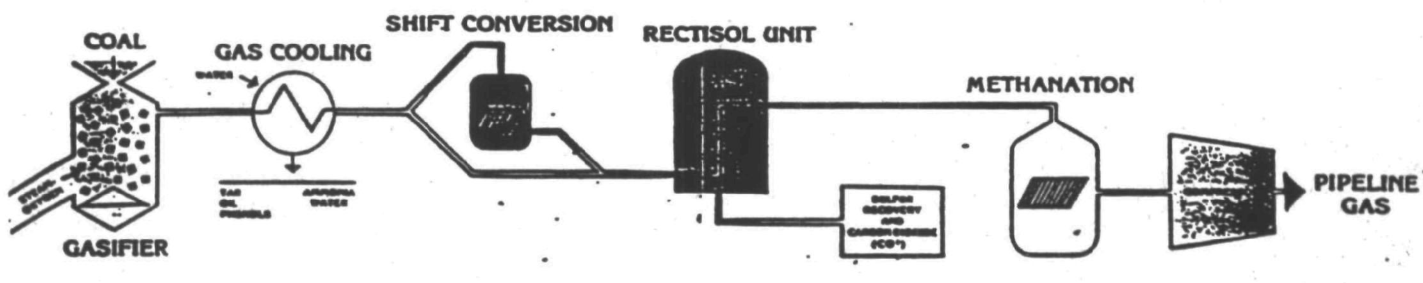

FIGURE 3. SIMPLIFIED FLOW CHART OF THE PROCESS LEADING TO A PRODUCTION OF SYNTHETIC NATURAL GAS AT THE GREAT PLAINS COAL GASIFICATION PROJECT, BEULAH, ND

A few environmental highlights follow:

- The facility's most serious operating problem was experienced at its three Stretford sulfur recovery units. The state permit allowed a maximum of 1,340 lb/hr of SO_2 emissions, but the total of stack and flare emissions have totaled 5,000 - 7,000 lb/hr. Although the plant has now been operating for nine years, it is believed that SO_2 emission problems still persist.

- The process water management system was designed to have a negative plant water balance and zero wastewater discharge to surface waters, but in the early years of operation, there was water discharge during the winter months to a tributary of the Knife River. During summer months there is no discharge due to the high evaporation rates in the several cooling ponds.
- The largest solid waste discharge is ash — about 1,100 tons per day. RCRA-mandated EP toxicity tests performed on the ash indicated that this material is non-hazardous. An ash disposal area was prepared in the lignite mining area. This area was lined with compacted clay that was 5 feet thick at the base and 14 feet thick at the side walls.

Texaco Gasifier/Tampa Electric IGCC Project

This project is now under construction at Tampa Electric Company's Polk (County) Power Station at Lakeland, FL. The project will demonstrate an integrated gasification combined-cycle (IGCC) system using Texaco's pressurized, oxygen-blown, entrained flow gasifier technology, incorporating both conventional, low-temperature acid-gas removal and hot-gas moving-bed desulfurization. The Texaco-based system has already been proven capable of handling both subbituminous and bituminous coals. This demonstration project scales up the technology from Cool Water's 100 MW to 260-MW.

Texaco's pressurized, oxygen-blown, entrained-flow gasifier is used to produce a medium-BTU fuel gas. Coal/water slurry and oxygen are combined at high temperature and pressure to produce a high-temperature syngas. Molten coal-ash flows out of the bottom of the vessel and into a water-filled quench tank where it is turned into a solid slag. The syngas from the gasifier moves to a high-temperature heat-recovery unit which partially cools the gases.

The cooled gases flow to a particulate-removal section before entering gas-cleanup trains. About 50 % of the syngas is passed through a moving bed of zinc-titanate absorbent to remove sulfur. The remaining syngas is further cooled through a series of heat exchangers before entering a conventional gas-cleanup train where sulfur is removed by an acid-gas removal system. These cleanup systems combined are expected to maintain sulfur levels below 0.21 lb/million BTU (96 % capture). The cleaned gases are then routed to a combined-cycle system for power generation. A gas turbine generates about 192 MW. Thermally generated NO_x is controlled to below 0.27 lb/million BTU by injecting nitrogen as a cooling diluent in the turbine's combustion section. A heat-recovery steam-generator uses heat from the gas-turbine exhaust to produce high-pressure steam. This steam, along with the steam generated in the gasification process, is routed to the steam turbine to generate an additional 130 MW. The IGCC heat rate for this demonstration is expected to be below 8,500 BTU/kWh (more than 40 % efficient, making it attractive for baseload applications). Figure 4 is a schematic flow diagram of the project. Byproducts from the process — sulfur, sulfuric acid, and slag — can be sold commercially, the sulfur and sulfuric acid byproducts as a raw material to make agricultural fertilizer, and the nonleachable slag for use in roofing shingles, asphalt roads, and as a structural fill in construction projects.

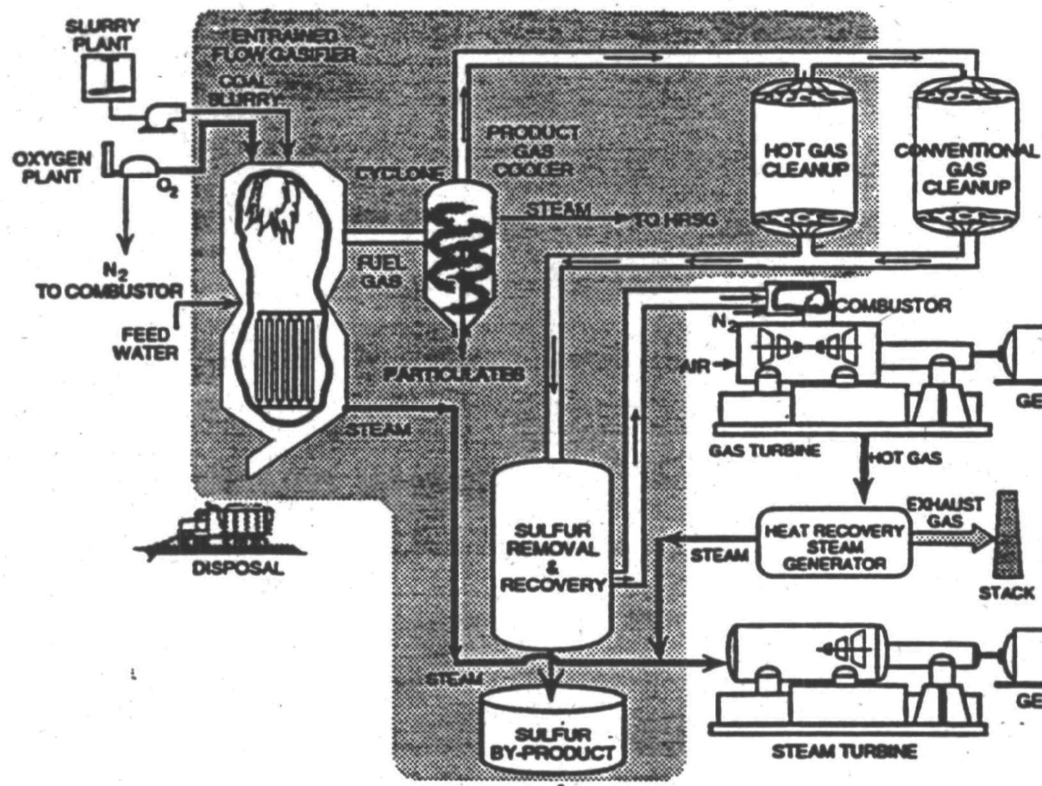

FIGURE 4. TAMPA ELECTRIC INTEGRATED GASIFICATION COMBINED-CYCLE PROJECT, BASED ON TEXACO ENTRAINED-FLOW GASIFIER

Commercial IGCCs should achieve better than 98 % SO_2 capture with NO_x emissions reduced by 90 %.

The Texaco gasification process is versatile as it can be used to gasify a number of feedstocks, including coal, petroleum coke, "Orimulsion" (a tar/water emulsion based on Venezuelan tars), heavy oils, and other hydrocarbons, and even industrial and domestic wastes such as trash and paper. In addition to the Florida project, the Texaco gasification process is being operated or being built at two locations in Delaware, ten locations in China, and three locations in Italy.

U-Gas Gasifier/Toms Creek IGCC Project

The project is to be built near Coeburn, Wise County, Virginia, at Virginia Iron, Coal, and Coke Company's Toms Creek Mine. The 190 MW project is based on the Institute of Gas Technology's "U-Gas" gasifier.

The objective of the project is to demonstrate air-blown, fluidized-bed gasification, combined-cycle technology, incorporating hot gas cleanup, for generating electricity and to assess the system's environmental and economic performance for meeting future energy needs. It will also demonstrate the newly developed zinc titanate fluidized-bed hot-gas cleanup technology.

Coal is gasified in a pressurized, air-blown, fluidized-bed gasifier in the presence of a calcium-based sorbent. About 90 % sulfur removal is accomplished in the gasifier. Solids entrained in the gas are collected by cyclones in two stages. The low-BTU gas, which leaves the secondary cyclone at 1,800 - 1,900 °F, is cooled to about 1,000 °F before entering the post-gasifier desulfurization unit where zinc titanate is used to remove the bulk of the remaining sulfur in the gas. This is accomplished in two fluidized beds. In the first bed, the sulfur is absorbed by the zinc titanate; the zinc titanate is regenerated in the second bed. In the final hot-gas-cleaning step, a ceramic candle filter removes particulates. The gas is then sent to the gas turbine combustor which has been modified to burn low-BTU gas.

Hot exhaust gases from the gas turbine are directed to a heat recovery steam generator. The steam generated is used both for driving a conventional steam turbine generator to produce additional electricity and to provide steam feed to the gasifier. Figure 5 is a schematic flow diagram of the project.

About 430 tpd of bituminous coal are converted into 55 MW by the gas turbine. A conventional pulverized coal boiler produces another 135 MW through the shared steam turbine generator. Also, 50,000 lb/hr of steam are generated for export to a coal preparation plant located next to the demonstration facility. The electric power is sold to a utility.

The U-Gas technology is capable of gasifying all types of coals, including high-sulfur and high-swelling coal feedstocks.

The total system being demonstrated is compact, reducing space requirements, and is amenable to small capacity, modular construction. There are no significant wastewater streams, and the solid waste from the gasifier, ash and calcium sulfate, is disposed of as a non-hazardous waste.

The heat rate of the demonstration facility is expected to be 8,720 BTU/kWh (39 % efficiency) with SO_2 emissions reductions of 99 % (0.056 lb/million BTU release). NO_x emissions are expected to be 0.09 lb/million BTU.

Corollary Processes

Shift Conversion

The water gas shift reaction is of immense importance. In this reaction, carbon monoxide (CO) reacts with water (as steam) over a catalyst to produce hydrogen and carbon dioxide. The

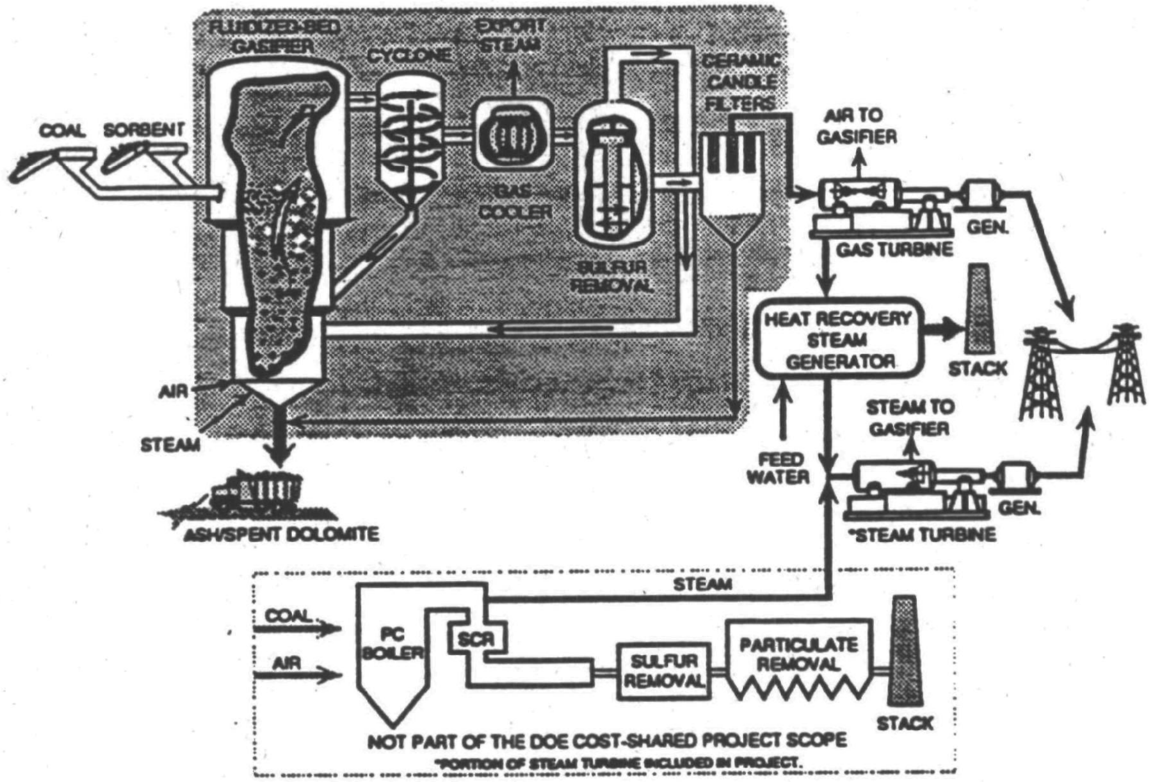

FIGURE 5. TOMS CREEK IGGC DEMONSTRATION PROJECT BASED ON INSTITUTE OF GAS TECHNOLOGY U-GAS COAL GASIFIER

reaction, which is reversible, is used to prepare hydrogen or a synthetic gas with a higher H_2/CO ratio than the feed gas. The reaction is exothermic, is unaffected by pressure, and favors H_2 production as reaction temperatures are decreased (315 - 510 °C; 600 - 950 °F). Product gases having CO concentrations of 0.2 - 0.5 % are possible. However, if the desired product is an oxygen-containing chemical such as methanol, then a ratio of H_2/CO_2 close to the theoretical of 2/1 is desired, since

$$CO + 2H_2 \rightarrow CH_3\,OH \text{ (methanol)}$$

The water gas shift reaction is therefore used after coal gasification when products such as hydrogen, methane (SNG), methanol, and other organic chemicals are the desired final product.

Methanation

The catalytic hydrogenation of carbon monoxide to methane occurs at elevated pressures. Favorable temperatures for the reaction are in the range of 230 - 450 °C (445 - 840 °F). Many suitable catalysts have been discovered, but nickel-based catalysts are used almost exclusively for industrial applications. The reaction is highly exothermic, therefore heat removal must be efficient to minimize loss of catalyst activity or plugging of the reactor due to nickel carbide formation. This reaction is used, in conjunction with the water gas shift reaction, when pure methane (SNG) or a methane-rich gas is desired.

Compression and Drying

Considerable volumes of water are co-produced during the methanation reaction, therefore the product gas is cooled to condense some of the water. In subsequent multistage compression steps, followed by cooling between each compression step, additional water is condensed and drained off.

Current Trends

Supply and Demand

By the mid-1990s, more than half of all existing coal-fired boilers in the United States will be 30 years old or older, and the percentage of aging plants will rise even more sharply around the year 2000. At the same time, demand for electricity is continuing to increase. As much as 100,000 to 150,000 megawatts of additional new capacity beyond what is currently planned — the equivalent of 200 to 300 moderately sized (500-megawatt) power plants — could be required by the end of the century.

These two trends — aging power plants and growing electricity demand — pose serious problems for utilities wishing to use coal unless new technology is available. Today's baseload coal-fired power plant takes 10 to 12 years to design, permit, and build. It is probably too late to count on major new baseload construction to meet much of the new power demand by the year 2000.

Many clean coal technologies, however, can replace older power plants, not only reducing emissions but extending lifetimes by 20 to 30 years. Because of the higher efficiencies, the new technologies can boost an older plant's electrical output by 40 to 200 %. For some installations, the effect could be the equivalent of two or more power plants at the original plant site, with sulfur emissions reduced as much as 99 % and NO_x emissions lower by 40 % than the older plant. Coal gasification may also become the technology of choice for future, new plant construction.

Repowering technologies, in general, replace a major portion of an existing plant (such as the boiler) with new power generating equipment while retaining other portions of the plant (such as the steam generating equipment). Pollution control considerations are inherent in repowering, but more effective pollution control is not the only advantage. A repowered plant can produce more power — sometimes twice as much or more — than the original plant, and extend the plant's lifetime by 20 to 30 years.

Repowering comes into play when existing coal-fired plants reach the end of their useful lives — typically 25 to 40 years after they were built — and a utility must decide whether to retire or rebuild the facility. Repowering also becomes attractive when power generation needs have increased and a utility wants to avoid the problems of finding and obtaining approval for a new site. Many repowering concepts also rely on standardized, shop fabricated components. This minimizes the costly, customized, on-site construction required for conventional technologies.

Integrated coal gasification combined cycle technology is not the only repowering technology available, but it is certainly a prime candidate considering its environmental advantages. Other repowering technologies include atmospheric and pressurized fluidized bed combustors.

Improvements in Gasification Technology

The next generation of gasification combined cycle power plants will likely employ the hot gas cleanup techniques currently being developed. These techniques remove sulfur and other impurities in the fuel gas stream at much higher temperatures than today's technology, eliminating or minimizing the efficiency-robbing cooling step.

One such technology sends the hot coal gas through a bed of zinc ferrite particles. Zinc ferrite can absorb sulfur contaminants at temperatures in excess of 1,000 °F, and the compound can be regenerated and reused with little loss in effectiveness. During the regeneration stage, salable sulfur is produced. The technique is capable of removing more than 99.9 % of the sulfur in coal.

Other potential technical advances are currently in research and development, and as they are proven, they will be incorporated in industrial-scale facilities.

Fuel Cells Based on Hydrogen and Oxygen (Air)

Unlike other coal systems, fuel cells do not rely on combustion. Instead, an electrochemical reaction generates electricity. Electrochemical reactions release the chemical energy that bonds atoms together — in this case the atoms of hydrogen and oxygen. The concept is much like a battery, except fuel cells produce electricity (and usable heat) as long as hydrogen and oxygen are fed to them.

The fuel cell is extremely clean and highly efficient. In a clean coal technology configuration, the fuel cell is fueled by hydrogen extracted from coal gas made by a coal gasifier. Techniques exist to clean and purify the coal gases and the principal waste products from the fuel cell water. Fuel cells are often categorized by the substance used to separate the electrodes, termed the "electrolyte." The most mature fuel cell concept is the phosphoric acid fuel cell. These cells have been used in hospitals, apartment buildings, and shopping centers and are now being developed for utility use. Other concepts are being developed. One is the molten carbonate fuel cell which uses a hot mixture of lithium in potassium carbonate as the electrolyte. The newest type is the solid oxide fuel cell which uses a hard ceramic material instead of a liquid electrolyte.

Scale of Operations

During the last several decades, a number of 800 - 1300 MW base-loaded power plants were built. Economics of scale and the highest possible thermal efficiency were among the factors leading to the construction of such large units. Future projects for such power plants are more apt to be built and operated in modular fashion in increments of 100 - 300 MWs. This offers not only increased reliability (several modules can be operated more reliably than a single large plant) but also shorter construction times (construction periods of 3 to 4 years, rather than 5 to 8 years for the large units). Utilities would also be able to match demand patterns more quickly and precisely.

Geographic Distribution of Coal and Coal Gasification Projects

From the viewpoint of producing electrical power from coal in the United States, it is expected that the greatest concentration of future coal gasification projects will be located at or near coal-producing sites. This is an economic necessity since the cost of transporting coal by rail or truck over long distances is much more expensive than the cost of transmitting electrical energy. Coal deposits occur in 38 of the 50 United States (see Figure 6), however these deposits are missing or meager in eastern states including New York, New Jersey, and all the New England states, plus Florida, Georgia, South Carolina, Minnesota, Wisconsin, California, and Nevada. Where the cost of importing coal is excessive, public utilities have several alternatives for power generation: import electrical power, or produce power from imported or locally produced natural gas and petroleum products.

In very general terms, the predominant coal in the midwest and eastern deposit is bituminous coal with a relatively high sulfur content. Western coals are mostly subbituminious coal and lignite, with lower sulfur content. The choice of coal gasification technology selected for a given site depends somewhat on the type of coal available, but most of the recently developed coal gasifiers are flexible with respect to their coal handling requirements.

In-situ or Underground Coal Gasification

In underground gasification, steam and oxygen are injected into a coal seam through wells drilled from the surface. The coal seam is ignited and partially burned. Heat generated by the combustion gasifies additional coal to produce fuel-grade gases. The gases are piped to the surface where they are cleaned and processed using the same techniques applied in surface gasification.

Underground gasification may be particularly useful in extracting energy from coal seams that are unmineable. Seams that slope steeply from the surface or are too deep or of marginal quality may be future candidates for *in-situ* gasification.

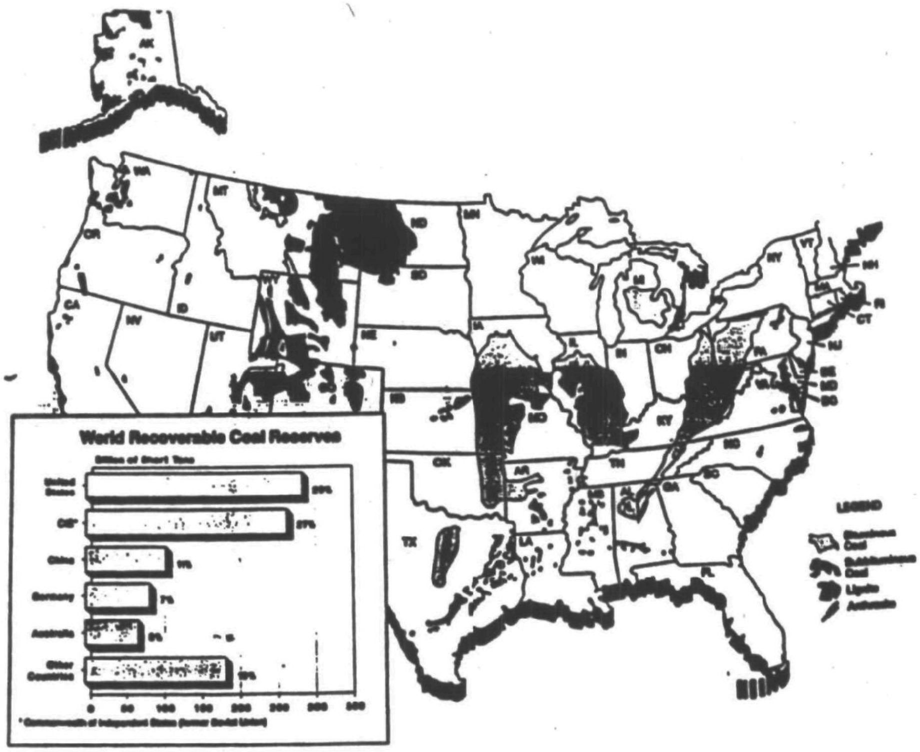

FIGURE 6. OCCURRENCE OF COAL IN THE UNITED STATES

Since the earth serves as the gasification reactor and repository for residual ash, and since the coal mining and transportation steps are not needed, the economics of in-situ gasification are very attractive. However, depending on site geology and hydrogeology, environmental risks associated with possible aquifer contamination and eventual land subsidence may be considerable. We do not believe that this technology is under development in the United States at this time, but, allegedly, the Russians are experimenting with these technologies.

Combatting the Greenhouse Effect

The earth's temperature is largely regulated by atmospheric gases. Carbon dioxide (CO_2), methane, and other gases such as nitrous oxides and chlorofluorocarbons (CFCs) allow the sun's energy to penetrate to the earth, but trap the heat radiated from the earth's surface. This phenomenon has been termed the "greenhouse effect."

There is some uncertainty in the estimates of the global budget of these greenhouse gases. Although the sources of most of these gases have been well characterized, the sinks for them have not been defined with certitude. However, it has been estimated that U.S. coal combustion contributes as much as 8% of the total worldwide release of CO_2 attributable to anthropogenic activities.

Some technological improvements can offer alternatives to regulations for mitigating the CO_2 release from coal combustion. For instance, many coal technologies are effective in reducing CO_2 because they increase power generating efficiencies. In higher efficiency systems, less CO_2 is produced per unit of fuel consumed. For example, technologies like pressurized fluid bed and gasification combined cycle boost energy utilization efficiencies into the 40% to 45% range. This can reduce CO_2 emissions by 17% to 27% over conventional coal technologies. Future technologies such as gasifier/fuel cell combinations could lower CO_2 emissions by up to 40%.

4. ENVIRONMENTAL DOCUMENTATION

EPA's NEPA regulations (40 CFR Part 6) specifically assigns EPA the responsibility for determining whether their proposed action (issuing a NPDES permit) will cause significant environmental impacts. EPA is also responsible for the scope and content of the environmental assessment and draft and final EISs. The regulations, however, indicate that "Information necessary for a proper environmental review shall be provided by the permit applicant in an environmental information document." EPA staff is directed to consult with the applicant on the scope of the information that the applicant provides.

In preparing these guidelines, it was assumed that EPA staff would typically ask the applicant for information in a format that is easily incorporated into a Draft EIS and would be most familiar to agency NEPA reviewers. The standard order for a Draft EIS is identified in EPA NEPA regulations 40 CFR Part 6.201:

(a) Cover sheet
(b) Executive Summary
(c) Table of contents
(d) Purpose of and need for action
(e) Alternatives including the proposed action;
(f) Affected environment
(g) Environmental consequences of the alternatives
(h) Coordination (including list of agencies, organizations, and persons to who copies of the EIS are sent)
(i) List of preparers
(j) Index (commensurate with complexity of EIS)
(k) Appendices.

The remainder of this document follows the order of the body of the EIS: purpose and need, alternatives, affected environment, environmental consequences, and summary topics. Unlike an EIS, it does not present a specific project and its environmental effects, but discusses the kinds of data, analyses, methodologies, and qualitative and quantitative approaches EPA staff are likely to consider in a data request to a new source NPDES permit applicant.

5. PURPOSE AND NEED

The "Purpose and Need" section of an EIS requires the clear specification of the underlying purpose and need to which EPA is responding. In the case of new source facilities, the purpose and need section must specify the goals and objectives of the applicant. The purpose and need must be a clear, objective statement of rationale for the project.

The importance of the statement of purpose and need is that it identifies and describes the alternatives evaluated and the selection of the chosen action. The alternatives that must be considered are those that fulfil the purpose and need, not just alternatives to a proposed project. If the purpose is to build a new petroleum refinery, the alternatives could consider other locations or a different delivery schedule. If, on the other hand, the purpose is to provide transportation fuels to meet fuel demands, the alternatives could include conserving fuels through fuel-efficient vehicles, different kinds of fuels (gasohol, LPG), different locations, or a combination of some of the above. The more extensive the range of possible alternatives, the greater the possibility of avoiding significant impacts.

The applicant for a new source petroleum refinery or coal gasification facility would most likely be responding to a perceived future demand for fuels and should consider all the options available to them. Since the only alternatives that need be considered are those that can fulfill the stated purpose and need for the project, the choice of the purpose and need statement is critical to a full examination of possible alternatives and the selection of the chosen action.

The information requested of the applicant needs to elicit a clear demonstration of why the project is needed. Typically, historical and projected data from a number of different sources (e.g., local or regional governments, state energy management or regulatory agencies, institutions, community groups) are used to present a clear need. The applicant should demonstrate, in this section, that a full range of options were considered before a new facility was proposed.

6. PROJECT ALTERNATIVES

The "Alternatives" section of the EIS contains descriptions of all alternative actions or projects that were, or are, being considered. Reasonable alternatives are explained in detail. Alternatives that were considered and rejected early in the planning process are briefly described with the rationale for their dismissal. Dismissed alternative are usually those that are unreasonable for technical, economic, or institutional reasons. The rationale must have sufficient data to support the decision not to proceed with dismissed alternatives and sufficient backup data to respond to a challenging question or comment on the Draft EIS.

New source NPDES permit EISs have several different general categories of alternatives: alternatives available to EPA, alternatives considered by the applicant, and alternatives available to other permit agencies.

Alternatives Available to EPA

EPA has three basic alternative actions that can be taken on new source NPDES permit applications:

(1) Take the action (i.e., grant the permit)

(2) Take the action on a modified or alternative project, including one not considered by the applicant

(3) Deny the action (i.e., reject the permit application).

The third option is usually called the "no action alternative."

Alternatives Considered by the Applicant

The applicant should provide to EPA, as part of the NPDES permit application, EID, or other data, a detailed description of each reasonable alternative they considered and a brief description of the alternatives they considered and rejected. A "no project alternative" should also be described.

The "no project alternative" of the applicant and the "no action" alternative of EPA are not the same even though the outcome may be the same. EPA's action relates to making a decision on whether or not to grant a NPDES permit, while the applicant's "no project alternative" relates to not achieving their goal (e.g., not meeting consumer demand for fuels). The applicant may be able to achieve their goal through some other means (alternative) that does not require a NPDES permit (e.g., alternative fuels).

EPA NEPA regulations (40 CFR Part 6.203 [b] [1]) require: (1) "balanced" descriptions of each alternative considered by an applicant and (2) discussion covering "size and location of facilities, land requirements, operations and management requirements, auxiliary structures such as pipelines or transmission lines, and construction schedules."

When large fuel needs are projected, companies typically undertake screening processes and feasibility studies to help them identify and refine reasonable alternatives. The companies investigate fuel types, siting, process types, and other topics. These screening processes provide the bases for determining various alternatives that can be identified and investigated further.

The siting process typically includes analyses of constraints and opportunities for conflicts such as the presence of critical habitat for an endangered species, an important historical site, or an active earthquake fault as well as other physical, hydrologic, biological, land use, access, economic, and air quality parameters. Siting studies may be used for new source facility locations, pipelines, transmission lines, or other facilities; each with different criteria and rankings.

As part of the description of alternatives, the applicant's screening processes and results should be explained to provide insight into the breadth and depth of alternatives considered and rejected or pursued for further study. Explaining how the applicant narrowed the list of alternatives can significantly reduce questions on whether conservation and demand side management were considered, non-traditional fuel sources were given fair consideration, particular locations for pipelines or transmission lines were chosen, and many others. A well-documented explanation of the screening processes of the applicant is critical to complying with the requirement for a thorough consideration of alternatives. A description of the screening process is also often required by state or local agencies.

Alternatives Available to Other Permitting Agencies

The third category of alternatives are those available when EPA is preparing a joint EIS or other environmental document with another federal or state agency. These additional alternatives relate to the other federal, state, or local entity's discretionary decisions or permits and typically include: grant the permit; grant the permit with modifications; or deny the permit.

Proposed Projects

The applicant may have a proposed project or may wait until the final EIS is being prepared to identify a preferred alternative from among several alternatives that are fully described. The message is clear in both the CEQ and EPA NEPA regulations that a broad array of alternatives need to be considered, and at least several reasonable alternatives need to be explored in detail and compared. The detail on the reasonable alternatives necessary from the applicant must be sufficient so that the potential impacts of the alternatives can be identified and compared. As with all the of the information needed for the EIS, the applicant's environmental documentation or EID must provide sufficient detail so that the environmental consequences can be evaluated and compared.

A "rule of thumb" is to provide the nature and the magnitude of "inputs" and "outputs" of each facility in the description of each alternative. Inputs and outputs include the physical/ chemical materials involved in construction of facility operation as well as biological, social, and institutional (e.g., employment, land use, access) information and costs.

7. AFFECTED ENVIRONMENT

Identifying and Characterizing the Affected Environment

This section discusses the methods and means of identifying and characterizing potential effects on the physical-chemical, biological, and socioeconomic environments; land use; visual resources; and cultural resources. It identifies only those environmental elements that are significant in determining impacts. The affected environment section of an EID should to be no longer than needed to present information required to understand environmental impacts. Background information on topics not directly related to expected effects should be summarized, consolidated, or referenced to focus attention on important issues.

Many of the following sections indicate that the affected environment is more than what currently exists—it is also a projection into the future. The essence of impact assessment is to determine what will happen with (because of) the project compared to what would have happened if the project had not been built. The most appropriate time for impact assessment is that point in facility construction or operation that creates the greatest change over the current environment. For new source facilities, this is usually at some time during construction.

Physical-Chemical Environment

The physical-chemical environment comprises the air, water, and geological characteristics of sites where the environmental impacts of alternatives will be evaluated. This section should provide sufficient information to determine whether impacts on these resources will be likely, but should not dwell on information that is of only esoteric interest. Typical information needs for this section are specified below.

Air Resources

Air resources are described by the physical dynamic behavior of the lower atmosphere and by variations in the concentrations of various gases and suspended matter. Physical dynamic behavior is described by parameters such as the seasonal distribution of wind velocity and the frequency and height of inversions. Wind velocity and the frequency of occurrence of inversions are often determined by specific local topographic features, particularly surrounding hills or mountains. Air quality is described by the variations in the concentrations of pollutant gases in the lower atmosphere. Both are needed to determine the environmental impacts of facility stack emissions, the effects of mobile sources on local air quality, and the likelihood that dust will be of importance during construction.

The description of meteorological regime(s) should include a generalized discussion of regional and site-specific climate including:

- Diurnal and seasonal ground-level temperature

- Wind characteristics at different heights and times (wind roses are particularly helpful and provide wind speed, direction, frequency, and stability characteristics of the atmosphere)
- Total monthly, seasonal, and annual rainfall and frequency of storms and their intensity
- Height, frequency, and persistence of inversions and atmospheric mixing characteristics
- Description of pattern(s) evident for days of significant pollution episodes; evaporation.

Under certain circumstances (where cooling ponds are integral to facility design, for example), humidity, dew point, and evaporation rates also provide useful data for determining water balances.

Existing ambient air quality is required to predict the resulting air quality during construction and operation of a facility. Using existing air quality as the background, incremental increases in air pollution concentrations can be predicted for comparison with various federal, state, and local standards. Depending on the scale of the analysis, data should be presented for the relevant airshed, for the site itself, or both.

Emission inventories and ambient air quality as reported by state and local air pollution control districts are the data sources for an air basin or regional airshed level analysis. At a minimum, major stationary sources and their emissions should be characterized, with diurnal variations in emissions by month, year, and peak season for pollutants of concern. Projections of increases in emissions and long-term pollutant concentrations are also important at this level. The comparison of future trends with existing federal, state, and local standards becomes a major design parameter for gaseous emission controls.

Site-level analyses are more detailed in their geographic scope, but require similar information. One of the major concerns at the site level is the transport of odors, dust, and emissions towards potentially sensitive environments. Thus local variations in wind velocities, frequency of inversions, and ambient pollutant concentrations may become important in determining local impacts. Air quality models are often used to determine the directions and ground level concentrations of pollutants of concern, and these models require most of the information described in the previous paragraph along with specific stack characteristics such as stack height, emission temperature, emission velocity, and the chemical composition of the stack gases.

Water Resources

Information on water resources to be included in the affected environment chapter should cover a description of local streams, lakes, rivers, and estuaries, as well as descriptions of groundwater aquifers. Descriptions of water body types, flows and dilutions, pollutant concentrations, and habitat types near potential discharges are necessary to determine the changes in the water environment that will occur with facility construction and operation. Descriptions of groundwater aquifers are necessary to determine the potential for contamination of groundwaters from site activities. Of key importance here is the depth to the water table, and the nature of overlying soils and geologic features.

Descriptions of surface waters should include seasonal and historical maximum, minimum, and mean flows for rivers and streams, and water levels or stages and seasonal patterns of thermal stratification for lakes and impoundments. The use of surface waters (diversions, returns, and reclamation) may also be important. Information on ambient concentrations of pollutants is also necessary to determine resulting concentrations of pollutants with new discharges.

Descriptions of groundwaters should include the location of recharge areas, and, in areas of water shortage, their present uses. Chemical composition of groundwaters are not usually important unless they are to be used as process water or are suspected to be contaminated.

If imported water is to be used at the site for process water or other purposes, the source, quantity, and quality of the water should be described.

If the site might be subject to flooding (is within the 100-year floodplain), the dates, levels, and peak discharges of previous floods should be reported along with the meteorological conditions that created them. Projections of future flood levels should also be included for typical planning levels of 50- and 100-year floods. These projections should include anticipated flood control projects such as levees and dams that will be built in the next few years.

Soils/Geology

The physical structure of soils and their underlying geologic elements determine the extent to which soils will be affected by facility construction and operation. Useful parameters include permeability, erodability, water table depth, and depths to impervious layers. The engineering properties and a detailed description of surface and subsurface soil materials and their distribution over a site provide most of the information necessary.

Nevertheless, local and regional topographic features such as ridges, hills, mountains, and valleys provide information on watershed boundaries, and site topography (slope and elevation characteristics) provides information that is needed in determining the potential for erosion.

Geological features are important when there may be significant mineral resources present or when paleontological sites and other areas of scientific or educational value may be disturbed or overlain by facility structures.

Information on seismic events is usually not required in an EID since sites that are near faults or seismically active areas are generally screened from consideration during siting studies. Nevertheless, if there might be concern about earthquake damage to a facility, the history of earthquakes in the area provides useful information to evaluate risks. Relevant parameters include locations of epicenters, magnitudes, and frequency of occurrence.

Biological Environment

The distribution of dominant species and identification and description of rare, threatened, or endangered species of vegetation, wildlife, and ecological interrelationships are the three important biological environment elements needed to identify and characterize the affected environment.

Vegetation

In order to understand the significance of vegetation changes associated with construction and operation of a facility, it is necessary to know the types of plant communities in the general area and the specific distribution of vegetation types on the site itself. The presence in the area of rare, threatened, or endangered species and unique plant assemblages are particularly important, especially if any are likely to occur at the site. There are a variety of ways to describe vegetation, but the most useful is to divide the site flora into four or five "typical" assemblages and map their distribution along with recognized scientific and educational areas. For threatened, endangered, or rare species, however, it is necessary to map their occurrence separate from the assemblages.

In arid areas, fire hazard should be described by describing the history of fires in the area, projecting the severity of fire hazard in the future, and describing existing fire control and management actions.

Aquatic and marine vegetation should be described as for terrestrial vegetation if sedimentation and aquatic discharges are likely to be large in relation to the size of the receiving waters.

Wildlife

The presence of wildlife at a site is largely dependent on the nature and distribution of terrestrial vegetation. Particular emphasis should be placed on the presence of rare, threatened, or endangered species in the general vicinity of the site, and site-specific discussions are mandatory when the site provides habitat that is used by rare, threatened, or endangered species. Under these circumstances, the relative abundance of all rare, threatened or endangered species and the dominant wildlife fauna should be surveyed on site and presented in the EID. Otherwise, a general description of the wildlife species that inhabit the area is sufficient if there is some discussion of the importance of the site in relation to their area-wide distribution.

Ecological Interrelationships

Ecological interrelationships between vegetation and wildlife are important in the existence of both components. These interrelationships should be characterized before establishing environmental impacts to either flora or fauna, and they differ slightly between terrestrial and aquatic environments.

It is probably not possible to determine the extent to which plants and animals are mutually dependent at a given site, but specific attention should be given to the food sources of dominant or rare animal species, the factors that limit these food sources (including factors such as soil structure and moisture content, soil surface temperature ranges, and specific soil micronutrients), and the ability of animal species to substitute food sources should current food sources be reduced in abundance. Ecological interdependencies in aquatic systems are also important, and aquatic communities change dramatically with large increases in nutrient or sediment discharges. While prediction of changes in plant and animal populations is difficult under the best of circumstances, significant changes (either positive or negative) cause concomitant changes in both terrestrial and aquatic fauna.

Socioeconomic Environment

The socioeconomic environment encompasses the interrelated areas of community services, transportation, employment, health and safety, and economic activity. The activities associated with the construction and operation of new source facilities must impact human resources (employment, population, and housing), institutional resources (services or facilities), and economic activity. The information required to assess impacts are described below.

Community Services

Community services such as water supply, sewerage and storm drainage, power supply, and education, medical, and fire and police services are almost always affected by major new projects. It is important in an EID to describe the nature of existing public facilities and services within the general vicinity, the quality of the service provided, and the ability of the existing public facilities and services to accommodate additional users. The most critical consideration is the level of services that would be provided in the anticipated peak year of construction assuming the project were to be built.

Permanent and temporary household relocations create demands on the housing market. The number of nearby housing units, their cost, vacancy rates, and owner-occupancy rate are all significant factors in determining the suitability of the existing housing stock for occupancy by a temporary or permanent workforce. In addition, the present rate of growth within the housing sector can be compared with the anticipated growth in housing supply and demand and the amount of land available for new housing to determine whether existing policies and attitudes toward growth are adequate to accommodate the additional residents.

Transportation

Transportation systems provide access to a facility for the import of raw materials, export of final products, and the movement of staff and service personnel. All relevant forms of transport for the facility should be described. For all facilities, road-based transport is of potential significance, but railways, airways, pipelines, and navigable waterways may also be important for some facilities. Secondary impacts to air quality resulting from transportation requirements should be evaluated in accordance with the Clean Air Act. Current traffic volumes, current traffic capacity, and an assessment of the adequacy of the systems for meeting peak demands during construction or operation should be presented.

Population

Total population, rate of growth, general socioeconomic composition, transient population, and the urban or rural nature of the local population are parameters needed to assess the importance of the impacts of project-induced changes on the local community. Information on average household size, average age, age/sex distributions, ethnic composition, average household income, percent of households below poverty level, and median educational level allow a more refined analysis of project-induced changes. Projections of demographic trends for the region and project area without the project are also necessary to determine the relative impacts of the project in future years.

Employment

Employment is generated by the construction and operation of any new facility. Construction is normally carried out by a temporary workforce of construction workers, not by the permanent workforce in the area near the site. On the other hand, facility operation usually relies on a permanent workforce, and the source of personnel for this workforce may be local or from other parts of the country. In any case, increases in the number of personnel required to build or operate a facility, direct employment, is accompanied by increases in employment in enterprises required to support the facility, indirect (secondary, non-basic) employment, as demands for goods and services are increased. The direct and indirect employment generated by a project, in turn, generates movements of households, resulting in population shifts and changes in the demographic characteristics of communities.

To determine impacts of additional employment on the local environment, it is necessary to present information about the local labor base—where people work, what they do, their skills and education level, their rates of pay, and the unemployment rate. The characteristics of the unemployed population are especially important if there is an expectation that a new facility will generate employment for them.. Projections should also be included on anticipated trends in employment and unemployment without the project so that project-induced changes in these parameters can be compared against a baseline.

Health and Safety

Description of the present health and safety environment should include statistics on industrial accidents in the local area; a discussion of air, water, and radioactive emissions from existing facilities and their effects on the health of the local population; and an analysis of present levels of noise and their impacts on people. The identification of applicable regulatory standards provides a benchmark against which the present and future health and safety environment, with and without the project, can be judged.

Economic Activity

Economic activity will always be affected by new facilities. Current economic activity should be described by characteristics of local businesses (number and types of businesses, annual revenues, and ownership patterns) and the availability of capital for future growth. To predict changes in the kinds of economic activity that would occur with the project, it is necessary to describe the kinds of goods and services that would be required by the project or associated workforce and determine whether they are provided locally or imported. Unique features of the business community such as high seasonality, high outflow of profit, declining trade, or downtown revitalization should also be included.

Land Use

A description of land use should identify the current use of land needed specifically for the facility, its system components, its safe area, and its residuals, and land use patterns in the nearby area that will be indirectly affected by the project. Particular emphasis should be placed on land uses that pose potential conflicts for large-scale industrial activity — residential areas, agricultural lands, woodlands, wetlands — and on the local or regional zoning laws that may limit the development of industry or commercial activities on which it relies.

Aesthetics

Aesthetics involve the general visual, audio, and tactile environment (imagine the sensory differences among urban, industrial, agricultural, and forest environments). A description of the aesthetic characteristics of the existing environment should include things that are seen, heard, and smelled in and around the site and their emotional or psychological effect on people. Descriptions (or pictures) of views of the site, of unique features or features deemed of special value, and public use and appreciation of the site provide information that must be available for the assessment of impacts.

Cultural Resources

Cultural resources encompass several areas relating to man's knowledge and appreciation of prehistoric and historic events. The location of a facility at or near significant historical and cultural sites tend to degrade their resource value or emotional impact. The location of the following kinds of sites should be described in relation to the project site:

- Archeological sites (where man-made artifacts or other remains dating from prehistoric times are found);

- Paleontological sites (where bones, shells, and fossils of ancient plants or animals are found in soil or imbedded in rock formations);

- Historic sites (where significant events happened or where well-known people lived or worked);

- Sites of particular educational, religious, scientific, or cultural value.

8. ENVIRONMENTAL CONSEQUENCES

The "Environmental Consequences" section forms the scientific and analytical basis for the comparison of alternatives. It contains discussions of beneficial and adverse impacts of each reasonable alternative and mitigation measure (40 CFR Parts 1502.16 and 1508.8) including:

(a) Direct effects and their significance — direct effects are caused by the proposed action and occur at the same time and place.

(b) Indirect effects and their significance — indirect effects are those caused by the action but are later in time or farther removed in distance, but are reasonably foreseeable. This also includes growth effects related to induced changes in the pattern of land use, population density, or growth rate and related effects on air, water, and ecosystems.

(c) Possible conflicts between proposed actions and the objectives of federal, regional, state, local and ... tribal ... land use plans, policies, and controls for the area concerned.

(d) The environmental effects.

(e) Energy requirements and conservation potential.

(f) Natural or depletable resource requirements and conservation potential

(g) Urban quality, historical and cultural resources, including reuse and conservation potential.

(h) Means to mitigate adverse environmental impacts not fully covered by the alternatives.

The potential impacts of each alternative are identified by a systematic disciplinary and interdisciplinary examination of the consequences of implementing each alternative.

Methods of Analysis

While information may be gathered from new source NPDES applications, EIDs, and other sources, EPA is responsible for the scientific and professional integrity of any information used in an EIS. The applicant's EID and other sources of data, therefore, must clearly explain all sources, references, methodologies, and models used to analyze or predict results. Applicants should consider the uses and audiences for their data and EPA's affirmative responsibility in using them. EPA has the same responsibility in the use of data submitted by other agencies, private individuals, or groups.

Each impact has its own means of identification, qualification, and quantification. For example, air quality impacts are modeled using standard state- or federally-approved programs. These numerical models depend on standardized parameters and site-specific data. Stationary source emissions from plant operation as well as mobile emissions related to traffic circulation from induced employment or growth all contribute to air quality impact quantification. The goal is to quantify impacts on air quality, water quality, employment, land use, and community services — categories that lend themselves to numerical calculations, modeling, and projections. Some environmental elements like aesthetics lend themselves to more qualitative or graphic analyses.

Biological impacts frequently are not readily quantifiable because absolute abundance of individual species are difficult to determine. Impacts may be described as acres of habitat lost or modified or to qualitative impact descriptions of population changes in major species or species groups. The key in the Environmental Consequences section is to clearly and succinctly lead a reader through each impact identification, qualification and/or quantification. Detailed methodologies or extensive data can be incorporated by reference if the source is readily obtainable. Materials from applicants must carefully follow this pattern to facilitate validation and incorporation in the EIS. General impacts likely to occur with new source facilities are identified in later sections along with suggestions on the kinds of information needed to analyze data and draw conclusions.

Determination of Significance

The term "significant effect" is pivotal under NEPA, for an EIS must be prepared when a new source facility is likely to cause a significant impact. What is significant can be set by law, regulation, policy, or practice of an agency; the collective wisdom of a recognized group (e.g., industry or trade association standards); or the professional judgment of an expert or group of experts. CEQ (40 CFR Part 1508.27) explains significance in terms of context and intensity of a action. Context relates to scale — local, regional, state, national, or global; intensity refers to the severity of the impact. Primary impact areas include affects on public health and safety, and unique characteristics of the area (e.g., historical or cultural resources, parks, prime farm lands, wetlands, wild and scenic rivers, or ecologically critical areas). Other important factors include:

- Degree of controversy over effects of human encroachment
- Degree of uncertain or unknown risks
- Likelihood a precedence will be set
- Occurrence of cumulative impacts (especially if individually not significant)
- Degree to which sites listed, or eligible for listing, in the National Register of Historic Places may be affected
- Degree to which significant scientific, cultural, or historical resources are lost
- Degree to which threatened or endangered species or critical habitats are affected
- The likelihood of violations of federal, state, regional or local environmental law or requirements.

In its new source NPDES program, EPA's environmental review procedure (40 CFR Part 6.605) indicates that the responsible officer shall consider short- and long-term effects, direct and indirect effects, and beneficial and adverse effects. The published specific criteria identify some of the natural and man-made environmental elements whose significant impact would trigger the preparation of an EIS. According to the regulations, an EIS will be prepared when:

(1) The new source will induce or accelerate significant changes in industrial, commercial, agricultural, or residential land use concentrations or distributions which have the potential for significant environmental effects. Factors that should be considered in determining whether these changes are environmentally significant include but are not limited to:

- The nature and extent of the vacant land subject to increased development pressure as a result of the new source;
- The increases in population or population density which may be induced and the ramifications of such changes;
- The nature of the land use regulation in the affected areas and their potential effects on development and the environment; and
- The changes in the availability or demand for energy and the resulting environmental consequences.

(2) The new source will directly, or through induced development, have significant adverse effects upon local ambient noise levels, floodplain, surface or groundwater quality or quantity, fish, wildlife, and their natural habitats.

(3) Any major part of the new source will have significant adverse effect on the habitat of threatened or endangered species on the Department of the Interior's or a state's list of threatened and endangered species.

(4) The environmental impacts of the issue of a new source NPDES permit will have significant direct and adverse effect on property listed in the National Register of Historic Places.

(5) Any major part of the source will have significant adverse effects on park lands, wetlands, wild and scenic rivers, reservoirs, or other important bodies of water, navigation projects, or agricultural lands.

With the regulations in mind, it is ultimately up to EIS preparers to make judgments on what constitutes a significant impact. The threshold of significance is different for each impact, and those making the judgments need to explain the rationale for the thresholds chosen. Clear descriptions of the choice of the threshold of significance provides a reviewer with a basis for agreeing or disagreeing with the determination of significance based on specific assumptions, criteria, or data. Sometimes the thresholds are numerical standards set by regulation. In other cases, the thresholds may be set by agency practice (e.g., the U.S. Fish and Wildlife Service may consider the potential loss of a single individual of an endangered species as a significant impact), or the EIS preparer's professional judgment determines the rationale for the threshold. The NPDES permit applicant may suggest a threshold for each impact in the EID, but it is critical to carefully define how and why each particular threshold was chosen and applied.

Comparisons of Impacts under Differing Alternatives

Alternatives may be compared in several different ways. All the impacts associated with a single alternative may be examined together and summarized in a final list of significant unavoidable impacts, or the like impacts of all the alternatives can be determined and compared within a final summarized list of significant unavoidable impacts. The choice of approach should be determined by the EIS preparers based on the approach that would provide the most clear, concise evaluation for decision makers and reviewers. The summary information on possible impacts and mitigation measures is usually prepared in tabular form and included in the executive summary. Examples of formats that can be used are found in standard environmental assessment technology texts, agency manuals, EISs, and similar documents.

Summary Discussions

CEQ and EPA NEPA guidelines describe the expected general contents of the section called "Environmental Consequences." In addition to identifying, quantifying, and comparing the impacts of each alternative, 40 CFR Part 1502.16 specifies that discussions will include "...any adverse environmental impacts which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long term productivity, and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented."

Over the last 20 years, these three topics have been included as a separate chapter(s) in draft EISs along with chapters called cumulative impacts, adverse effects which cannot be avoided, or residual impacts and mitigation. No matter what format is used with these topics, they often receive only cursory treatment. Such a practice is unfortunate because these long term, larger scale issues are those that affect overall environmental quality and amenities. The important point is not the location of these topics in the document, but the need to present data and analytical procedures used to qualify and quantify these concerns.

A section called cumulative impacts can be addressed in several ways. Some EISs consider cumulative impact sections to be summaries of all residual impacts for each alternative. They may also include any synergistic effects among impacts. A second, and more helpful, approach to cumulative impacts reflects a broad view of environmental quality and suggests how impacts of the proposed project or alternatives contribute to the overall environmental quality of the locale. In this approach, the impacts of the new source project are considered in relation to the impacts associated with projects approved, but not constructed; projects being considered for approval; or planned projects. This "accumulating" impacts approach to cumulative impacts is particularly instructive when no single project is a major cause of a problem, but contributes incrementally to a growing problem.

All of these summary topics focus on broad views and long time lines in an attempt to put project impacts in perspective. The data requests from EPA to applicants must specify the environmental setting and consequences data needed to qualify and quantify the potential impacts and put each potential impact in perspective in terms of local, regional and perhaps state or national environmental quality. The question to be answered is: what part do the project-related impacts play in local/regional/state/national environmental quality now and in the future for each affected parameter.

Mitigation Measures

Early in the history of NEPA, emphasis was placed on identifying mitigation for all possible impacts conceivably associated with a project or its alternatives. Now the emphasis is on avoiding and minimizing potential impacts long before a NEPA document is prepared. This is accomplished by refining the proposed project and alternatives during siting, feasibility, and design processes. The goal is to have project alternatives with as few significant impacts as possible.

CEQ NEPA regulations define mitigation (40 CFR Part 1508.20) to include:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

This listing of mitigation measures has been interpreted as a hierarchy with "avoiding impacts" as the best mitigation and "compensating" for a loss as the least desirable (but preferable to loss without compensation). This hierarchy reinforces the present approach of trying to avoid or minimize potential impacts during project siting and design. The goal is to have the most environmentally sound project and alternatives to carry into the impact assessment process of NEPA.

Even with the best project siting and design, there will be environmental impacts associated with each of the alternatives. For the impacts, especially for the impacts judged to be significant impacts, mitigation measures need to be suggested.

The first source of possible mitigation measures should be those offered in an applicant's EID. Each mitigation measure should be described in enough detail so that its environmental consequences can be evaluated and any residual impacts clearly identified.

The proposed project and its alternatives — or the suite of alternatives if there is no preferred alternative — typically reflects choices among tradeoffs. The tradeoffs can include different sites, processes, pollution control technologies, costs, or other features. Typically the tradeoffs are complex for new source facilities with dissimilar beneficial and detrimental impacts among the alternatives. The analysis should be deemed complete if:

(1) the alternatives brought forward for analysis are all reasonable;

(2) all possible refinements and modifications for environmental protection have been incorporated in the alternatives; and

(3) any residual impacts and consequences of mitigating those impacts have been evaluated.

Decision makers are then confronted with comparing the alternatives based on tradeoffs, often requiring value judgments.

General Impacts

The rest of this chapter on environmental consequences is organized into two major sections. The first presents information on the impacts associated with facility construction and operation from a general point of view. In this section, specific impacts that may be caused by new source facilities are outlined, without reference to specific processes or activities associated with different industries. The second section covers industry-specific impacts — those impacts that result from the kinds of facilities covered in this guidance.

New source facilities are often large and frequently cover hundreds of acres of land. Facility operation requires a sizable infrastructure including internal transportation networks for raw material and product transport, loading and unloading areas, fuel and raw material storage areas, production facilities, waste control and treatment facilities, and waste storage or disposal areas.

Because of the large land area required for these facilities and the diversity of activities required to operate them, there are a range of impacts that essentially cannot be avoided. The most noticeable impacts are associated with site preparation and construction — the changing of one land use to another — but there are also ongoing and indirect impacts associated with facility operation that should be covered in an environmental impact assessment.

The general impacts associated with new source facilities are discussed in the following two sections. The first section covers impacts associated with site preparation and construction; the second with facility operation.

Impacts from Site Preparation and Construction

Site preparation and construction for large, complex facilities includes some degree of land leveling and soil compaction and the erection of production facilities, raw material loading and unloading areas, raw material storage areas, waste storage and disposal areas, and a transportation system for moving materials from one area to another. In the first stage of construction activity, land is cleared and prepared for the storage of building materials, for transporting materials between the storage areas and building sites, and for the building sites themselves. For very large facilities, stone crushing, concrete mixing, and other materials processing facilities may also be built on-site. These activities affect the immediate area in predictable ways. The impacts associated with site preparation and construction are discussed below under the following headings:

- Habitat alteration
- Pollutant generation
- Socioeconomic impacts.

Habitat Alteration

The extent to which habitats are affected by site clearing and grading depends on the extent to which natural ecosystems were previously disturbed. Conversion of a wooded and previously undisturbed area results in greater changes than conversion of a previous industrial site. The habitats associated with heavily vegetated areas are almost always more plentiful and diverse than those associated with previously used sites.

The majority of habitat impacts stem from clearing and grading land. The removal of native vegetation has a direct effect on some species by removing their protective cover, food sources, or roosting, nesting, or breeding sites. It can have indirect effects on others by exposing bare soil, which is more subject to erosion, leading to sedimentation in a nearby waterbody, smothering habitat used by aquatic plants and animals. The removal of vegetation and compaction of soils by construction machinery also increases the rate of runoff following rain, increasing the volume of water that must be carried by local streams, and increasing the rate of stream bank erosion and habitat smothering. The removal of shade over streams also increases water temperatures, sometimes reducing the value of the stream for cold water species of fish.

Even if natural habitats are not completely destroyed by clearing and grading, they may lose their value for some species because they become fragmented. Some species require a minimum size of a particular habitat type in order to survive. If the habitat is broken up, even if only by a road, the size of the available habitat type may be sufficiently reduced to prevent their continued survival, and they leave the area or succumb.

Critical Issues:

- Will construction and site preparation activities alter critical habitats for wildlife impacting the local presence of such species?

  - Quantify areas and locations of habitats and associated species that would be lost or adversely affected during site preparation and construction activities.

- Would indirect changes in habitats following construction and site preparation activities occur? e.g., increased erosion potential resulting in habitat disturbance through sedimentation in waterbodies; disturbance of habitat and/or species from increased human access; accumulation of pesticides or construction chemicals in some habitats, and thence in wildlife and vegetation, etc.

  - Identify activities that would indirectly alter habitats. Quantify, to the extent feasible, the areas that would be indirectly affected.

Pollutant Generation

The most significant pollutants associated with site preparation and construction are dust and sediment resulting from land clearing. Dust and sediment may also be associated with toxic chemicals that tend to adsorb to particles. Dust tends to be a local annoyance, but can also blanket the vegetation in nearby areas, sometimes reducing its viability. Sediment from the site causes increased turbidity in nearby water bodies and may be deposited on stream bottoms, altering the nature of the substrate and changing stream bottom fauna from hard bottom or riffle communities to soft bottom communities. If the stream bottom community is changed, there will also be changes in the species of fish inhabiting the stream.

Uncontrolled construction site sediment loadings have been reported to be on the order of 35 to 45 times greater than loadings from undisturbed woodlands (typically less than 1 ton per year; Novotny and Chesters, 1981). In addition to disrupting stream bottom habitats as described above, the increased levels of turbidity also affect aquatic resources by reducing light penetration, and in turn reducing plant production in receiving waters.

Critical Issues:

- Would water quality be degraded by increased surface runoff (sediment and pollutant discharges), discarded or discharged construction materials and other chemicals, herbicides, wastewater, soil additives, disturbance of stream bed, or temperature increases due to increased turbidity or removal of vegetation?

  - Characterize sediment loading and compare loadings and predicted in-stream concentrations of associated pollutants with existing federal, state, and local water quality standards and criteria.

- Would there be increased overland flow, storm runoff, flood potential, stream bed sedimentation, or channel erosion due to increased runoff following site preparation and construction activities?
  - Determine the extent of stream damage caused by increased runoff (i.e., increased stream bed sedimentation, channel erosion).
- Would dust or air pollutants be generated from construction and site preparation activities?
  - Identify emission sources and project emission rates. Compare these rates to applicable federal, state and local standards and limitations (both emissions and air quality); compare predicted atmospheric levels with federal, state, or local standards.

Socioeconomic Impacts

In addition to the environmental impacts described above, the construction of new source facilities affects the local socioeconomic framework in many ways. These effects can be categorized as: (1) the compatibility of new land uses with existing land uses; (2) issues associated with human and institutional resources and impacts on community structure; and (3) effects on the local economy. Many of these impacts are initiated in the site preparation and construction phase, but they can continue in varying forms throughout the period the facility operates.

Land Use Change

Site preparation for the construction of new source facilities disturbs large areas of land and may change patterns of land use in the area. Open spaces (agricultural land, forested areas, or other vacant land) are often used for these facilities. Regardless of the land use of the original site, construction of these facilities disturbs large tracts of land and converts them to a new use that may not be compatible with, nor easily returned to, its original state. Industrial sites are not easily converted back to either forest, agricultural, or residential land. Thus the decision to build a facility at a particular site is essentially irreversible. Once construction has begun, the options for converting the site to other land uses become limited.

There are also changes in land use in the surrounding area. Housing is needed for the large construction crews required for these facilities, and construction workers generally prefer to live near the facility site. If the site is in a predominantly residential area, then housing will not necessarily be a problem (although housing values may decline if an industrial site is to be located in close proximity). If the site is far from a residential area, however, additional housing, often in the form of trailer parks, may develop in the immediate vicinity. In addition, small-scale commercial areas tend to develop around construction sites to provide food and sundries for workers and to provide construction support services.

Critical Issues:

- Would the construction and site preparation activities be compatible with the projected uses of adjacent, existing, or planned land uses. Is the site located in an area with existing or planned industrial facilities, or would the facility result in adverse aesthetic impacts or conflict with current or future residential, agricultural, or other land uses?

  - Identify the amount of existing or planned land use areas lost due to site preparation and construction activities. Describe expected changes in land use on nearby land.

- Does existing land availability, as determined by zoning and land use plans, conflict with site preparation and construction activities?

  - Determine to what extent zoning requirements and current land uses conflict with the facility site preparation and construction activities.

Human and Institutional Resources; Community Structure

The development of complex new facilities often generates extensive changes in the community structure of an area; many of these changes stem from changes in employment patterns. Construction of major facilities requires a large, trained work force that is often not locally available. Construction tends to attract workers from outside the immediate area. This influx of workers may not be significant in large and diverse communities, but in small communities, the entire economy can be changed, causing changes in employment patterns, population and population density, and housing, with implications for the adequacy of community services. If the facility requires a large work force during the operational phase, then these changes, usually temporary, could become permanent.

In small communities, the support of a large population of construction workers may require an expansion in community-provided services. Water supply, sewerage systems, and streets and roads might need modification or expansion. This expansion in community services can extend the environmental impacts associated with a new facility to other locations where new water treatment plants or streets and roads are needed. The construction of a new facility thus could contribute to changes in environmental quality that extend far beyond the immediate boundaries of the site.

The expansion in the labor force associated with new facility construction typically requires a buildup of support resources. Unfortunately, the number of people required to operate the new facility are often less than those required to construct it. Therefore, the influx of people could be temporary unless the community or larger geographic area has taken measures to accommodate displaced workers upon project completion. Depending on the success of the surrounding area to accommodate these people, there could be a withdrawal of workers from the area and a reduced need for the additional services that were once developed to accommodate them. This could negatively affect local economies, and in a worse-case scenario, entire areas (e.g., employee housing) could be abandoned.

Critical Issues:

- Would existing housing, community services, and infrastructure support a large temporary workforce during the site preparation and construction? What will happen to increased services after the site preparation and construction activities cease?

  - Identify the amount of deficient housing, community services, and infrastructure for the increased workforce during site preparation and construction. Determine services that will not be necessary after construction and site preparation cease.

- Is there a possibility of employment pattern changes from construction and site preparation activities? For example, will the area have increased employment and income directly and indirectly attributable to construction of the facility? Will construction of the facility compete with other projects or existing sources of employment for workers?

  - Determine the extent of changes in employment patterns attributable to site preparation and construction activities.

- Would there be a change in the community structure during and after site preparation and construction activities? Would the community life-style, structure, and stability be affected? Would there be difficulty in attracting professionals during and after construction? Would government jurisdiction(s) have difficulty accommodating changes in community structure?

  - Determine the extent of community structure changes caused by site preparation and construction activities.

- Are transportation facilities adequate for site preparation and construction activities? Would traffic congestion result?

  - Identify the transportation facilities needed for site preparation and construction activities; determine shortfalls in capacity.

- Would site preparation and construction activities present health and safety hazards to humans working on or near the site? e.g., increased possibility of accidents associated with the use of explosives or heavy equipment; exposure to noise from construction activities posing a health hazard.

  - Identify health and safety hazards to workers and the public due to site preparation and construction activities.

Loss of Historic or Cultural Resources

Just as clearing and grading activities remove existing vegetation and alter natural habitats, the same activities may affect historical, archaeological, or cultural resources. Site clearing activities may inadvertently collapse or undermine the structural integrity of archeological sites, or the facility might be built on an historical site. Even if these sites are preserved, their historical or archeological significance may be irrevocably damaged through the nearness of industrial activity.

Critical Issues:

- Would historical or cultural resources on the site be disturbed, destroyed, or covered over by site preparation and construction activities?
  - Identify historical and cultural resources destroyed or disturbed by site preparation and construction activities; include discussion of any mitigation necessary to preserve items of archeological, historical, or cultural interest.

Impacts from Facility Operation

This section presents information on the general impacts likely to be caused by facility operation. Topics are covered according to headings usually found in EISs — air quality, water quality, etc. — to facilitate review of EIDs. In general, the impacts associated with facility operation are not as severe as those associated with construction. Facilities cannot operate without obtaining permits for water discharges and air emissions, for example, and most permits are issued only after it is determined that environmental impacts will be acceptably small. Nevertheless, there are impacts that should be analyzed in an EID, and these are presented below.

Air Quality

New source facilities impact air quality through atmospheric emissions of particulates, hydrocarbons, carbon monoxide, carbon dioxide, sulfur oxides, and nitrogen oxides. Particulates result in a "dirty" or "dusty" atmosphere and accumulate on surfaces. Toxic chemicals also attach to particulates resulting in potential human health impacts if inhaled, and accumulation of toxic chemicals on land surfaces may cause environmental health impacts. Hydrocarbons and carbon dioxide are chemicals which are primarily responsible for the "greenhouse effect," by preventing the back radiation of heat from the earth's surface, increasing the temperature of the atmosphere. Carbon monoxide is a known toxicant, causing neurological and lung disorders, and even death. Sulfur oxides and nitrogen oxides are "acid rain" constituents, which, when dissolved in rain droplets, lower the pH of natural waterbodies, and destroy natural and man-made materials and structures. Emissions can also produce obnoxious odors affecting large areas in the vicinity of the site.

Air quality impacts can be determined quantitatively by comparing new source facility emissions with emission standards set by federal, state, or local governments, and by comparing the expected ambient concentrations of pollutants caused by facility emissions and other sources, with ambient concentration standards. EPA-approved models that should be used for these projections are discussed under industry-specific impacts.

Critical Issues:

- Will facility operations result in non-compliance with air emission and ambient air quality standards?

  - Identify emission sources and rates, including sources in the vicinity not associated with the site, and determine expected concentrations of pollutants in air. Compare emission rates and resulting concentrations to applicable federal, state, and local standards and limitations.

- Would stack emissions from the facility have deleterious effects on visibility and light scattering (i.e., cause smog?); damage natural or man-made materials and structures (i.e., cause acid rain?); adversely affect human health, domestic animals, wildlife, or vegetation?

  - Characterize stack emissions during operation and maintenance activities and compare with existing federal, state, and local standards.

Water Quality

Impacts to water from new source facilities range from water quality degradation from discharged toxics to hydromodification changes associated with increased impervious area, soil exposure, and erosion. Pollutants may enter surface waters from wastewater disposal to land, effluent discharges, or precipitation runoff from raw material or product storage areas. Nutrients (nitrogen and phosphorus compounds) in water can lead to eutrophication—excess plant growth resulting in algal blooms, weed-choked waterbodies, and fish kills. Toxic contaminants result in acute and chronic toxicity to aquatic biota as well as possible human health affects with ingestion of contaminated water. The temperature regimes of receiving waters may be changed through warm water effluents. Increases in ambient temperatures generally reduce biodiversity and limit the abundance of cold water fish species. The possibility of water quality impacts can be determined by modeling the concentrations of contaminants in receiving waters caused by process and stormwater discharges, and comparing the results with water quality standards. EPA-approved models that can be used for this purpose are found in the industry-specific impacts section.

Critical Issues:

- Will toxic pollutants and/or organic matter from wastewater disposal, effluent discharges, or precipitation runoff from storage areas have deleterious effects on groundwaters or surface waters?

  - Model pollutant concentrations in groundwaters and surface waters and compare with existing federal, state, and local water quality standards and criteria.

- Would the facility cause adverse environmental impacts to the receiving water body?

  - Estimate the discharge plume's short and long term impacts to the biological community.

- Would there be a change in the temperature of receiving waters because of heated effluents?

  - Predict receiving water temperature distributions around and below cooling water discharges. Compare results with federal, state, or local standards.

- Would facility operation cause increased sedimentation and habitat destruction by altering the existing flow patterns of water courses?

  - Determine which aquatic habitat might be impacted, and to what extent.

Soil Quality

The majority of the impacts to soils occur during site preparation and construction. As enumerated in the previous section, these include: soil loss due to the removal of top soil during the clearing and grading process; soil compaction and erosion; reduction in the productive capacity (i.e., fertility) of the soil; potential soil contamination; and a general loss of soil resources due to coverage by impervious areas.

After plant operations begin, the potential for soil contamination is high in raw material/product loading and unloading areas, materials storage areas, and/or in production areas of the facility where spills may occur. The potential for soil contamination is also high in areas used for on-site waste storage or treatment facilities. Frequently land treatment units or landfills are used; sometimes waste materials are stored in piles (e.g., ash piles). Contaminant runoff or leachate from these areas can percolate through soils to groundwater.

In addition to the potential for soil contamination during the operating phase of the facility, soil erosion and sedimentation can still occur. The extent of the problem depends on the effectiveness of the erosion control techniques used to stabilize the site after construction, especially on steep slopes and/or areas that are allowed to remain without vegetative cover.

Critical Issues:

- Would there be decreased soil permeability due to compaction from operation and maintenance activities? Are there indirect and direct losses of soils through erosion caused by improper protection of exposed soils?

  - Determine the potential for soil loss during facility operation. Discuss mitigation activities to be used to reduce erosion.

Vegetation

As described earlier, construction of new source facilities removes much of the vegetative cover. The impacts associated with these actions vary, depending on the site, but can be particularly acute if environmentally-sensitive or ecologically-important areas are affected (e.g., wetlands, riparian zones). In most cases, this lost natural vegetation is not replaced, either because so much of the area is rendered impervious, or because the land is disturbed to a point that it will no longer support native vegetation. Often, the replanting that does occur is done for aesthetic purposes; land is converted to turf grass, or ornamental landscaping plants are used. While attractive, these non-native vegetative covers do not offer the same level of environmental protection, nor ecological value of the natural vegetation.

The absence or scarcity of vegetation removes or reduces pollutant buffering capacity of the site, contributing to some of the following impacts:

- Increased potential for pollution, especially water pollution as runoff will be enhanced (volume and velocity) and can enter water bodies directly without the filtering effects of vegetation.
- On site conditions can be more severe, with wider temperature fluctuations, higher noise levels, and greater winds generating dust.
- Probable reduction in the numbers of species and abundance of wildlife species composition.

Critical Issues:

- Would there be permanent loss or displacement of vegetation habitat, and therefore floral species (rare, endangered, unique or unusual species, communities or habitats) because of the facility?

  - Identify critical habitats and associated species which would be not be restored following facility construction. Rare, endangered, unique or unusual species, as well as ecosystems, communities and habitats should be included within the assessment.

- Would changes in species composition, diversity, and number occur in the vicinity of the facility?

  - Identify changes in local species composition, diversity, and number resulting from loss of specific types of habitats.

- Would air and water quality degradation from toxics produced during operation and maintenance activities pose hazards to area flora (resulting in death, illness, reduced reproduction, etc.)?

  - Determine the extent of hazards to vegetation from air and water quality degradation.

Wildlife

The impacts to wildlife are primarily associated with changes that occurred during site preparation and construction. However, many of the impacts are carried over into the production phase and remain throughout the life of the facility. Habitat restoration is often impossible during operations because of irreversible damage done to soils and topography and the construction of buildings, roads, and storage areas.

As described previously in this section, the habitat loss associated with vegetative removal can have many far-reaching effects ranging from direct impacts on species depending on the removed vegetation to indirect impacts, such as water quality degradation and stream habitat damage resulting from the changing site conditions associated with site denudation. All of these impacts affect the food supplies and living conditions of countless species, ranging from the smallest microbes to large animals. Food sources may be destroyed, modified, or contaminated; nesting and breeding locations obliterated; ranges fragmented; and travel/migration routes irrevocably altered by the activities and infrastructure involved in constructing and operating a new source facility. All of these conditions affect the composition, distribution, abundance, health, and vitality of species.

Critical Issues:

- Would there be permanent loss or displacement of wildlife habitat, and therefore faunal species (rare, endangered, unique or unusual species, communities or habitats) because of the facility?

  - Identify critical habitats and associated species which would be lost during construction and not replaced during facility operations. Rare, endangered, unique or unusual species, as well as ecosystems, communities and habitats should be included within the assessment.

- Would change in species composition, diversity, and number occur in the vicinity of the facility?

- Identify changes in local species composition, diversity, and number caused by human activity.

- Would air and water quality degradation from toxics produced during operation and maintenance activities pose hazards to area fauna (resulting in death, illness, reduced reproduction, etc.)?

  - Determine the extent of hazards to wildlife from air and water quality degradation.

- Would operation and maintenance activities restrict migration routes and daily movement corridors or disturb sensitive species from human encroachment?

  - Identify migration routes and movement corridors of sensitive species disturbed by facility operation.

- Is there a potential for mechanical damage to biota from water intake structures during operation and maintenance activities?

  - Predict the extent of mechanical damage to biota from water intake structures.

Environmental Health and Safety

The large size and complex array of operations that comprise new source facilities pose threats to the health and safety of workers and the general public. Some of the threats occur during the construction phase, but health and safety issues tend to be more prevalent during facility operations. The three biggest areas of health and safety concerns are industrial accidents, exposure to contaminants, and noise.

As described in the technology overview section of this document, many hazardous or potentially dangerous materials are used or manufactured directly by petroleum refineries and coal gasification facilities. Others are created as byproducts. Plant workers have frequent exposure to these materials, either through direct handling or exposure to fugitive dust and other air emissions, or from spills and accidents. The potential for accidents at these facilities is fairly high, as large quantities of raw material inputs must be used (and transported) around the facility and large volumes of waste are generated and must be handled during disposal.

Noise is a particularly challenging problem at these facilities. For example, in the case of petroleum refineries, sources of noise include high speed compressors, control valves, piping systems, turbines and motors, air cooled heat exchangers, and other cooling devices. These sources create noise levels that range from 60 to 110 dBs at a distance of one meter from the source (The World Bank, 1991); these levels may be high compared to U.S. Occupational Safety and Health Administration requirements.

Critical Issues:

- Would operation and maintenance activities present health and safety hazards to humans working on or near the facility site? Examples might be an increased possibility of accidents associated with the use of operation and maintenance equipment; exposure to emissions from operation and maintenance activities presenting a health hazard; or exposure to noise from operation and maintenance activities posing a health hazard.

  - Identify health and safety hazards to workers or the nearby public due to operation and maintenance activities.

Land Use

The presence of a new source facility in an area affects land use not only during construction (see previous section), but also after construction is complete. The major impact on land use is the conversion of nearby land from agricultural or other use to industrial use for supporting facilities or residential use to meet the needs of an expanded labor force. Unless the area is already industrialized, introduction of one of these facilities changes the character of the nearby land uses — open space will be reduced and population densities may increase.

Critical Issues:

- Do land use requirements for operation and maintenance activities (safe zone or buffer zones included) conflict with adjacent present or future land uses as planned by local, regional and state agencies?

  - Identify the amount of existing or planned land use areas lost due to operation and maintenance activities.

- Will induced growth around the facility change land use in ways that are counter to currently planned land uses for the area? Will the mix of land in the vicinity be irrevocably altered because of the facility?

  - Describe anticipated changes in nearby land use as a result of the facility. Evaluate potential conflicts, not identified during the construction phase, that would occur during operations.

Visual Resources

Just as land uses change due to the introduction of a large industrial facility, so do visual resources. Again, the extent of impacts depends on the condition of the visual resource prior to facility construction and how compatible new land uses are with old. The impacts to visual resources will be large if the new facility is located in a previously undisturbed or scenic area (e.g., near a national park).

Visual resources can be important in a cultural, historic, aesthetic, and psychological context. Because of the large size of new source facilities and the diverse array of structures and storage areas associated with them (e.g., items ranging from large buildings and stacks to tank farms and piles of coal or ash), the nature of the landscape can greatly change as a result of their introduction. The presence of these facilities can not only affect an area's viewshed, but also its natural topography (through extensive grading, presence of large waste piles), thereby changing the entire character of an area.

Critical Issues:

- Will facility operation alter or disrupt visual amenity of the area or other aesthetic attributes of the site?
  - Determine the extent to which operation and maintenance activities disrupt sensory attributes.
- Would facility operations provide for an aesthetically satisfactory work environment?
  - Determine if the facility components are designed with consideration given to human factors.

Cultural Resources

The impacts to cultural resources that occur during facility construction remain after operations begin. Although the National Historic Preservation Act requires mitigation of impacts to these resources, the success of these techniques is varied. Also, regardless of mitigation techniques used, the presence of a major industrial facility around a significant historical site removes that resource from its natural context and is likely to reduce its overall significance.

Critical Issues:

- Would the value of a mitigated cultural or historical resource be reduced because of the presence of the facility?
  - Identify historical and cultural resources that would be reduced in value by the presence of the facility, especially if impacts were mitigated.

Socioeconomic Impacts

As described in the previous section, many socioeconomic changes occur during the construction phase of new source facilities. These impacts are primarily related to the influx of a large, temporary workforce. Depending on the facility size, the number of workers required for plant operation may be comparable to, or much lower than, those required during the construction phase. If the work force is greatly reduced, reduced economic opportunities, down-sizing, and even recession may result because the service sector that was created to support the construction labor force lost its market. On the other hand, if the labor force remains constant, or increases, an enhanced economy can result from the influx of dollars spent on local products and services and an increased local tax base. As well, the presence of a new facility could attract additional businesses, and other support services, thereby, continuing to provide positive economic enhancements to the area. In the short term, the local infrastructure could be strained, but in the long term, development (perhaps even a shift to increased urbanization) is likely occur.

Although in many ways the presence of a large facility can induce positive changes to a local economy, it can also create negative impacts. Most apparent of these is the increased likelihood of environmental degradation associated with expansion. But also, some areas may suffer financially, as the presence of a big industry could drive down real estate values.

Critical Issues:

- Will the housing, community services, and infrastructure support required for supporting a large temporary construction workforce be necessary during plant operations? Will infrastructure development costs be able to be borne by the permanent workforce?
  - Identify any excess housing, community services, or infrastructure that would not be necessary during facility operation.
- Will facility operation cause increased or decreased employment and income, both direct and indirect, over the construction phase? Will the facility compete with other projects for employees?
  - Determine the extent of employment pattern changes attributable to changes from facility construction to operation.
- Will additional infrastructure or community services be required to support facility operation?
  - Identify the types and amounts of infrastructure or community services that are required to support facility operation.

Technology-Specific Potential Impact Reduction

The following sections discuss the technologies and other pollution control activities used by petroleum refineries and coal gasification facilities.

Mitigating Impacts in Project Design

There are a number of pollution control measures that can be applied in the design phase to effectively reduce waste streams and their associated environmental impacts. Many of these steps also reduce operation and capital costs and/or increase production. The EID should contain a discussion of the waste management alternatives considered and their applicability. Discussions of pollution control should include descriptions of effluents, emissions, source reduction, reuse and recycling options.

The maintenance activities required for optimum operations are partially defined during the design phase as well. Effective maintenance measures can also reduce waste streams. The applicant should describe proposed maintenance activities with potential inherent impacts in the EID.

Pollution control equipment and systems are expected to be designed into the refinery process and waste treatment operations. These measures can effectively reduce adverse impacts by the emissions and wastes that are generated. However, these systems may create other kinds of impacts, by creating more concentrated, smaller volume wastes, or by converting wastes to other compounds. Often a residual solid or liquid waste is generated. As examples, H_2S removal in a waste gas stream may leave other SO_X compounds in the exhaust, and waste treatment systems for aqueous streams may not have the ability to treat all of the complex organic compounds which may be in the wastewaters, leaving contaminants in the effluents. Therefore, the EID should include discussions of the expected levels of remaining products and contaminants after treatment processes, and plans for handling, treatment and disposal of residuals. Overall, all proposed pollution control systems should be well-designed, well-operated, and properly maintained to minimize other impacts.

Petroleum Refining

A variety of impacts may result from technology in use at a typical petroleum refinery. Impacts, as used here, encompass waste discharges and emissions generated from refinery processes and operations which enter the environment in air, water, and land, and the resulting effects caused by their handling and disposal.

Many technological and programmatic methods are available to refiners to reduce or eliminate these impacts. The sections that follow outline the major waste streams (water, air, and solid waste) and the resulting effluents and emissions, and methods of control.

Raw Materials Extraction, Transport and Storage

The raw materials used by refineries is typically crude oil. Impacts associated with crude oil exploration, development and production activities are not discussed in this report.

The crude oil is transported to the refinery by pipeline, tanker or truck. Upon arrival, the crude is shipped to storage tanks on-site at the refinery, for feed to process systems as needed. The crude oil is typically a mixture of crude oil, brines and suspended solids. Potential contaminants of concern include naturally-occurring hydrocarbon compounds, volatile and semivolatile organics, heavy metals, and nitrogen and sulfur compounds.

The volumes in transit create a potential for large spills in an emergency situation or accident. Small spills may also occur from equipment leakage, maintenance, or cleaning. Because of the location of refineries and their associated pipeline or tanker terminals, spills and leaks can produce discharges of crude oil into local waterways. The major impact of concern is associated with tanker and truck accidents and the spillage from a major tanker breakup. The EID should provide a discussion of the potential occurrence of and impact from tanker accidents where this mode of transportation is proposed to service the refinery facility.

Gaseous Wastes

Sources of air emissions and pollutants differ considerably among refineries and are a function of the size of the refinery, the type of crude oil feedstock, the product mix (which dictates the type and complexity of processes employed), and emissions or pollution control measures used.

In general, waste gases are emitted from exhaust stacks of fired equipment, tanks and vessels, flares, open ponds or pits, and equipment leaks (termed fugitive emissions). Additional intermittent sources result from maintenance activities such as shutdown and cleanout of equipment and process equipment safety valves.

The waste gases include numerous combinations of components, depending on the source. The components of concern that may cause environmental impacts are sulfur oxides (SO_X), nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulates. SO_X and NO_x are precursors for acid deposition, while NO_x and HC are the precursors to the formation of tropospheric ozone. Both ozone and acid deposition are secondary pollutant problems resulting from primary emissions of a different pollutant. Other airborne emissions which are of interest due to their potential for impact are toxic and carcinogenic contaminants such as asbestos, benzene, and mercury.

The EID should identify, describe (quantitatively), and evaluate all such refinery air emissions. Interim heat releases, start-up, shut-down, safety valve releases, leaks and any other potential sources of emissions should be documented in the EID.

Stack Emissions

The acid gases — for refineries, primarily hydrogen sulfide and sulfur dioxide — are emitted from exhaust stacks, sulfuric acid concentrators, liquid sulfur dioxide refining units, and sulfuric acid treating units. Hydrogen sulfide may also occur naturally in the crude oil feedstock.

Carbon monoxide is largely confined to flue gases from catalytic cracking regenerators and fluid cokers (unless coal or coke are used as fuel for refinery power plants).

Particulate emissions are generated from cokers, regenerators, and dust sources on-site. Construction and the local environment (a dry and dusty climate) may also add to the volume of air-borne particulates.

Nitrogen oxides are formed as a byproduct of combustion, so the main source of NO_x is from the exhaust stacks of fired equipment.

Fugitive Emissions

Fugitive emissions are essentially the gaseous leaks from refinery equipment that are not intended. Air permit regulations require fugitive emissions to be quantified, and some state requirements include quantifying all piping flanges and connections to estimate the total volume of contaminants released.

In the EID, the refiner should acknowledge the existence of fugitive emissions and present emission prevention measures to reduce impacts.

Air Quality Modeling

To facilitate attainment of regional and national pollution standards, it is common for industry and government to use computer and mathematical simulation to predict the migration and concentrations of pollutants in air. Air quality models of varying complexity and applicability are now available. The model or models appropriate for a particular task depend on many factors, including the accuracy and level of detail desired, the nature of available data, the capabilities of the modeling technicians, the resources available, and site-specific factors such as weather pattern characteristics. This next section outlines the basic types of air quality models preferred by EPA.

There are four basic types of air quality models: Gaussian, numerical, statistical or empirical, and physical. Gaussian models are the most commonly used steady state models (models that predict ambient pollutant concentrations at "equilibrium," not as they vary over time) since they do not require large amounts of data. Numerical models or time-varying models are often better suited to situations involving more reactive pollutants, but their large data requirements are often prohibitive. Statistical or empirical models are more appropriate when the data or knowledge of the relevant chemical and physical processes are inadequate for Gaussian or numerical techniques.

Physical modeling processes typically involve use of wind tunnels or other sophisticated equipment. While use of these complex models usually requires expensive equipment and technical expertise, they may be the best choice for complicated flow situations such as downwash conditions, diffusion in complex terrain, or plume effects on elevated terrain. Physical models are particularly suited to modeling sources in small geographic areas.

Most air models are designed to simulate impacts in two types of terrain: simple or complex. Simple terrain is terrain where land features are all below the height of the source stacks. Complex terrain has features that are higher than stacks.

Air models evaluate emissions from a number of source-types:

- Point sources, discrete single sources with known emissions..
- Line sources, used on roads and other linear sources, usually model mobile source emissions.
- Area sources, assumed when the emissions source is an uncovered lagoon, storage pile, slag dump, or other source with fairly uniform emissions over its entire surface.
- Volume sources, assumed when modeling fugitive emissions from structures with multiple exhaust vents or other sources characterized by multiple release points that have different individual emission rates.

Predicting concentrations at locations that fall between stack height and the height of maximum plume rise is more problematic. Modeling strategies for these cases are sometimes dealt with by comparing the hourly concentration estimates from simple terrain models and complex terrain models, and using the higher values. This technique often entails "chopping off" any terrain lying above stack height for the simple terrain models.

In addition to the terrain-specific design of many models, models generally come in two tiers of complexity:

(1) screening level models that use worst-case meteorological data to identify sources that may threaten air quality, and

(2) more advanced models that use actual meteorological data to give detailed descriptions of chemical and physical processes.

Screening models give "quick and dirty" estimates that are good enough to identify situations where air quality standards are not threatened. If these models predict that standards are likely to be exceeded, however, more detailed and expensive models need to be applied.

The models discussed below deal mainly with selected screening models preferred by EPA. The Urban Airshed Model (UAM) is the only refined analytical technique described here. Petroleum refineries are a significant source of VOCs, and UAM is considered by many to be the only model adequate for modeling VOC emissions from very large, disperse sources such as petroleum refineries.

EPA-Preferred Models

Based on factors such as past performance, cost, and availability, EPA recommends certain models for particular applications. Recommended screening models for simple terrain are described below, followed by screening models for complex terrain and the Urban Airshed Model. All of these models simulate pollutant transport in areas with less than a 50-mile radius.

Estimates of emissions can be obtained using emission factors published in EPA (1993b), or related information that is available from the CHIEFS bulletin board on EPA's Technology Transfer Network in Research Triangle Park, North Carolina (Telephone (919) 941-5384 or Internet, through Telnet to ttnbbs.rtpnc.epa.gov).

Simple Terrain Models

Climatological Dispersion Model (CDM 2.0)

The CDM is a Gaussian plume model designed to calculate long-term average pollutant concentrations (on either a seasonal or annual basis) at ground-level in urban areas. It may be applied in a variety of situations, including point and area sources, flat terrain, migration distances less than 50 kilometers, and averages over a period longer than one month.

Industrial Source Complex (ISC)

The ISC is a Gaussian plume model that is used to calculate pollutant concentrations from an array of sources associated with a complex industrial source. The model is designed to account for the following: downwash; settling and dry deposition of particulates; area, line and volume sources; separation of point sources; plume rise based on downwind distance; and limited terrain adjustment. It may be applied to industrial source complexes, rural or urban areas, flat or rolling terrain, and averaging times from one hour to one year.

Predictions of concentrations for area source emissions by ISC become more accurate the farther away the site is from the source (up to 50 km).

Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment (MPTER)

MPTER is a multiple point source model that can be used for predicting the concentrations of relatively non-reactive pollutants. MPTER may be used to model point sources, rural or urban areas, flat or rolling terrain that does not exceed stack height, and averaging times from one hour to one year. MPTER does not model area or volume sources as well as it models point sources.

Single Source Model (CRSTER)

CRSTER is another Gaussian plume dispersion program intended to estimate pollutant concentrations from point sources at a single location. It calculates the highest and second-highest concentrations for each receiving site over 1-hour, three-hour, 24-hour and annual averaging times. CRSTER is a suitable model for use with single point sources in either rural or urban areas.

Models for Complex Terrain

There are currently a number of complex terrain models sanctioned by EPA for regulatory use. Four of the more commonly used models are discussed briefly below.

Valley Model

The Valley Model is a slightly older (1977), steady-state, Gaussian univariate dispersion model appropriate for simulating plume impaction in either rural or urban settings for up to 50 point and/or area sources. It estimates concentrations at receptor sites designated by the program on a radial grid of variable scale. The algorithm used adjusts plume elevations according to stability class and height of the terrain impacted, and allows for limited mixing. It is recommended only for 24-hour averaging times, but can estimate annual concentrations as well.

COMPLEX I

COMPLEX I is a Gaussian dispersion model suitable for simulating multiple sources in rural areas. It is essentially a modified version of the MPTER simple terrain model, altered by incorporating a plume impaction algorithm. The model accepts hourly meteorological data as input, and can be used over all averaging times. Receptor sites may be placed on either a radial or cubic grid of variable scale. Because it is versatile and easy to use, COMPLEX I is often the model of choice for complex terrain in rural areas.

CTSCREEN

CTSCREEN is a screening version of the more refined Complex Terrain Dispersion Model (CTDM). One of its main features is it divides the mixing zone into several layers, as opposed to the other screening models listed here, which assume uniform mixing up to the top of the mixing zone. It may be used either in place of the Valley or COMPLEX I models, or as a tool to further investigate suspected problem areas. Some disadvantages of CTSCREEN are that it can require significant amounts of digitized terrain data to run, and it can simulate plume interaction with only one hill at a time.

SHORTZ and LONGZ

SHORTZ and LONGZ are the models of choice for complex terrain in urban areas. They may, however, be applied to flat terrain and rural areas. SHORTZ combines a steady-state bivariate Gaussian plume algorithm with sequential short-term (usually hourly) meteorological inputs to calculate average ground-level pollutant concentrations for averaging times from 1 hour to 1 year. It can simulate emissions from stacks, buildings, or area sources for up to 300 sources. LONGZ is a similar model, but differs from SHORTZ by employing a univariate Gaussian plume technique with statistical wind summaries to calculate long-term (seasonal and/or annual) concentrations from up to 14,000 sources.

Urban Airshed Model (UAM)

UAM is a three-dimensional urban scale numerical simulation model designed for use on entire airsheds. It is designed for calculating ozone concentrations formed under pulsed, short-term conditions (lasting 1-2 days) as a result of emissions of nitrogen oxides, carbon monoxide, and volatile organic compounds. As with CTSCREEN, UAM divides the mixing zone into several layers. It is suitable for urban areas with significant non-attainment for ozone, and hourly averaging times. As with other numerical models, it is very data intensive, making it unsuitable when data are not available, and potentially expensive when they are.

Waste Control and Residuals Disposal

To comply with air regulations and permit conditions, the refiner must employ air treatment systems, pollution control devices and reduction techniques to meet emission standards. The EID should contain a discussion of the type of control systems and anticipated resulting emissions levels.

Hydrocarbon emissions can be limited through the use of:

- Floating roofs on tanks;
- Manifolding purge lines to a recovery system (condenser or carbon absorber) or to a flare;
- Vapor recovery systems on loading facilities;
- Preventive maintenance;
- Enclosed waste treatment plant;
- Mechanical seals on compressors and pumps; and
- Personnel training.

Particulates can be controlled with the use of:

- Wet scrubbers;
- High-efficiency mechanical collectors (cyclones, bag houses); — electrostatic precipitators on catalyst regenerators and power plant stacks;

- Controlled combustion to reduce smoke;
- Controlled stack and flame temperatures; and
- Improved burner and incinerator design.

Carbon monoxide emissions can be controlled at the catalytic cracker and fluid coker units with a CO boiler and at other sites through proper furnace and burner design.

Sulfur dioxide emissions can be controlled primarily through:

- The burning of low-sulfur fuels in furnaces and boilers,
- The wet scrubbing of high-sulfur dioxide flue gases, and
- The removal of sulfur in fuels before use.

Nitrogen oxide emissions can be controlled through:

- An improved combustion process (i.e., lower flame temperature, less excess air)
- Use of low-nitrogen fuel.

Liquid Wastes

Refineries generate substantial volumes of wastewater. Typically, refinery facilities include extensive wastewater treatment systems on-site, where wastewaters are treated prior to discharge to natural waterways or to Publicly-Owned Treatment Works (POTWs). These wastewaters may contain high concentrations of oils and dissolved organics that are not readily biodegradable. They may also contain chemicals from processes, treatment, or maintenance that can pose environmental problems.

Refineries may have multiple wastewater collection and treatment systems, for cost effective design, operation and maintenance, such as process drains, stormwater collection systems, and sanitary sewers.

The EID should discuss the following:

- All wastewater streams (sources, quantities, flowrates, and compositions)
- Proposed wastewater treatment systems (capacities and processes)
- Effluent discharge stream (quantities, flowrates, and compositions)
- Potential hazardous or toxic chemicals in wastestreams
- Receiving waters quality and their use patterns.

Aquatic Discharges

Fluid or liquid wastewater streams that are typically generated at a refinery are briefly described below. The wastewater streams are typically treated on-site prior to discharging to a waterbody, where appropriate. This type of discharge is controlled through a NPDES permit.

The NPDES permit will have limits for numerous effluent constituents, such as BOD_5, hydrocarbons, metals, and acids. Wastewater treatment systems can be designed to remove the offensive constituents to proper levels, as evidenced by existing refinery operations.

Process Wastes

Liquid or fluid waste streams may be generated by processes or maintenance operations. The EID should describe each of the wastewater streams, its source and its destination.

Free oil originates from numerous sources such as individual sampling taps, pump gland leaks, valve and pipeline leaks, losses and spills at times of unit shutdown and equipment repair, accidental spills and overflows, tank bottom drawoff, and other miscellaneous sources. Some of the oil mixes with other fluids and becomes emulsified, making it more difficult to treat.

Condensate waters originate from distillate separators, running tanks and barometric condensers. These waters can contain a variety of chemicals such as sulfur-containing inorganics, acids, alkalis, suspended solids, and condensed organics.

Acid wastes arise from the catalytic use of various acids and from the acid treatment of gasoline, white oils, lubricating oils, and waxes. They occur as rinse waters, scrubber discharges, spent catalyst sludges, condensate, and miscellaneous discharges resulting from sampling procedures, leaks, spills, and shutdowns. Caustic wastes arise from caustic washing and may include sulfur and organic compounds. Alkaline waters also occur from washings.

Special solvents and numerous chemicals used in refining operations may be leaked or spilled and gathered into wastewater streams.

The highest wastewater volume is typically from cooling system blowdown, which can become contaminated with oil, chromates, biocides, and other chemicals used in cooling towers.

The sanitary wastewater stream can be easily treated on site in a separate treatment system, or can be sent to the local Publicly-Owned Treatment Works (POTW).

A wide variety of fluid sludges are generated from reactors, storage tanks, wastewater treatment and process equipment. These sludges may have a low percentage of solids. Sludges are typically dewatered or filtered to separate solids from the liquids, with the decanted liquids incorporated into wastestreams for treatment. Sludges may contain organics, sulfur compounds, and heavy metals.

Stormwater

Stormwater may be a large, yet sporadic, volume depending on the refinery size, location, and the local climate. The stormwater effluent may pick up a wide variety of hydrocarbon and chemical components from contact with the process and chemical storage areas. Stormwater is usually collected in a stormwater collection or sewer system, and may be sent to the refinery wastewater treatment system. Contaminant loading problems may occur in wastewater or runoff discharges if stormwater is not considered in the refinery design.

New refineries should consider alternatives for managing stormwater runoff. Recent Stormwater regulations under the Clean Water Act may impose certain requirements for monitoring and treatment. The EID should discuss the stormwater collection and treatment system design.

Water Quality Modeling

In this section, five water quality models are discussed. They are all relatively simple to operate, but the accuracy of their predictions depends largely on the adequacy of data used to calculate model parameters and characterize externally-driven functions such as water flow. The discussion of each of these models is taken primarily from EPA (1993a).

WASP4 (new version WASP5)

WASP4 is a detailed receiving water quality model supported by EPA. It allows users to interpret and predict water quality responses to natural phenomena and man-made stresses for various pollution management decisions, particularly for eutrophication (EUTROWASP) and toxicants (TOXIWASP). It is a dynamic compartment model and includes compartments for the water column and benthos. The model includes the time-varying processes of advection, dispersion, point and nonpoint mass loading, and boundary exchanges. It can be run in a one-, two-, or three-dimensional mode making it applicable to rivers, lakes, estuaries, or open coastal areas.

UTM-TOX

UTM-TOX was developed by the Oak Ridge National Laboratory for the analysis of hydrological, atmospheric, and sediment transport of pesticides and toxic substances. This model uses of a multi-media simulation approach. Given a chemical release to the atmosphere from a given source, the model uses mass balance formulae to compute chemical movement from a source, through the atmosphere, onto land, into surface runoff and through the soil, and finally in sediment and stream flow. The model generates summary tables and plots of average monthly and annual chemical concentrations in each medium. It also considers biotic processes and computes chemical accumulation in stems, leaves, and fruits of impacted vegetation. Application of this model has been limited because of its complexity and lack of user documentation.

EXAMS

EXAMS was developed by the EPA to provide rapid assessments of the behavior of synthetic organics in aquatic systems. Initial versions computed long-term results of continual, steady discharges of single chemicals into typical aquatic systems. A newer version includes routines that simulate seasonal variations of discharge, transport, and chemical transformations and predicts the transport and fate of reactants and products. The model requires extensive data on the physical properties of discharged chemicals and transformation products and for variables describing transport mechanisms and the physicochemical properties of receiving waters.

QUAL2E

QUAL2E is an EPA-supported, one-dimensional model that assumes steady state flow but allows simulation of diurnal variations in temperature, algal photosynthesis, and algal respiration. The model simulates a series of nonuniform segments that make up a river and incorporates the effects of withdrawals, branches, and tributaries. Conservative (non-degrading) and non-conservative water quality parameters can be handled. It is commonly applied to temperature, BOD, DO, ammonia, nitrate, nitrite, organic nitrogen, phosphate and organic phosphorus, and algae. QUAL2E is widely used to determine waste load allocations for streams.

SMPTOX

SMPTOX is a user-friendly, microcomputer program for screening-level modeling of toxic discharges to streams and rivers. It also provides a simplified method for allocating discharge loads for ammonia, chemical oxygen demand, and biological oxygen demand.

Groundwater Contamination

Groundwater contamination is not uncommon under or near existing refineries because of historical practices and other manufacturing that may have operated nearby. The existing condition of the local groundwater should be investigated by the refiners. If the desired location is near a contaminated aquifer, the refiners are faced with another set of concerns, and may face other requirements set by local agencies.

A new refinery should be designed to prevent groundwater contamination, and may install monitoring wells to monitor the local groundwater quality. Ideally, a new refinery operation should not result in groundwater impacts due to proper design and operation. The EID should contain a statement of the methods of prevention of groundwater contamination, and an assessment of existing groundwater conditions.

Groundwater Modeling

The use of air and water quality models is generally straightforward since the medium receiving, discharges or emissions can be considered to be well mixed, and predictions of concentrations of pollutants in these are relatively accurate. Such is not the case for most groundwater models. If is far less simple to model the predicted concentrations of pollutants in groundwater because of the physical structure imposed by soils and the general lack of detailed data concerning soil structure and soil-water relationships. Also, the chemical and physical nature of soils determines water movement and soil-pollutant-water interactions. The application of groundwater models is thus more of an art than a science, and considerable expertise is needed to select appropriate models and apply them appropriately. Nevertheless, there are some EPA-supported models that can provide some insight into the effects on groundwater of various waste management practices. These are described below.

PRZM

The Pesticide Root Zone Model is a dynamic compartment model that simulates the vertical movement of pesticides and other organic chemicals in unsaturated soil within and below the plant root zone. It is designed to predict movements of pesticides that are applied to soil or to foliage, and considers pulse loads, the prediction of peak events, and the estimation of time-varying mass emission or concentration profiles. The model has hydrology and chemical transport components that simulate runoff, erosion, plant uptake, leaching, decay, foliar wash off, and volatilization of pesticides. Predictions have a daily, monthly, or annual time frame (Ambrose and Barnwell 1989).

MULTIMED

MULTIMED simulates movement of contaminants in all media, no matter into which medium they are first released. In the groundwater part of the model, the movement of contaminants is simulated in saturated and unsaturated groundwater zones. MULTIMED uses a steady-state, one-dimensional, semi-analytical model to simulate flow in the unsaturated zone, the output of which is used as input to the unsaturated zone transport module. The transport module simulates transient, vertical transport, including the effects of dispersion, adsorption, and decay. Outputs from the unsaturated zone modules are used as input to the semi-analytical saturated zone transport module. The saturated zone transport module incorporates one-dimensional flow, three-dimensional dispersion, adsorption, decay, and dilution. The model is not appropriate for heterogeneous soils or interactions between different pollutants, both of which affect the behavior of contaminants in soil.

3DFEMWATER/3DLEWASTE

The 3DFEMWATER/3DLEWASTE groundwater flow and contaminant transport models consist of FEMWATER, a three-dimensional, finite element model of water flow through saturated-unsaturated media, and LEWASTE, a hybrid three-dimensional Lagrangian-Eulerian finite element model of waste transport through saturated and unsaturated media. The models simulate capillarity, infiltration, and recharge/discharge sources (e.g., lakes, reservoirs, and streams). The models consider steady-state or transient flow conditions in unconfined homogeneous, heterogeneous, isotropic, or anisotropic aquifers. Processes considered include advection, dispersion, adsorption, decay, precipitation, and discharging or pumping wells. The 3DLEWASTE model can simulate regional or local groundwater flow systems.

Spills

Spills result in emissions, effluent, and waste to be added to the refinery waste stream. The impact of spills depends on the location of the spill and the conditions of receiving waterbodies. The spills of greatest concern are those associated with transportation of large volumes of crude oil or products across waterbodies, and are discussed above.

Spills may occur during routine operations or maintenance activities. Spills are likely to be greater when containers or vessels are manually loaded or unloaded than with automatic transfer operations. Failure of tanks, vessels, or containers occurs infrequently. The refinery design should incorporate spill containment devices and spill prevention measures, particularly to meet the Clean Water Act's SPCC requirements.

The EID should contain a discussion of the types of spills that may occur and the response action planned. The refiner should also include spill prevention measures designed into the refinery operations and equipment.

Water Control and Residuals Disposal

Liquid wastes, or wastewater effluent streams are usually routed to an on-site wastewater treatment plant. The treatment plant design, with the effluent characteristics, flow rates, and outfalls should be discussed in the EID. The wastewater treatment and effluent discharge may be regulated by an NPDES permit, POTW requirements, or in some cases, a RCRA permit, or a combination of the three.

The wastewater treatment system design is dependent on refinery location, refinery plant size, the refining process (degree of crude finishing), and wastewater characteristics. The EID should demonstrate that the refiner has given adequate attention to implementation of new technology for abatement of water pollution. The EID should include an understandable and complete description of the proposed wastewater treatment system. A process flow diagram also should be provided to illustrate each step of the treatment scheme. Refineries may use the following basic treatment processes:

- Removal of free oil and suspended solids by gravity
- Removal of emulsified oil, suspended solids, colloids, and solids by coagulation and settling, sand filtration, and gas flotation

- Pretreatment to remove phenols, sulfides, mercaptans, and ammonia and adjust pH (with processes such as steam stripping, flue gas stripping, oxidation, and neutralization)
- Trickling filters, activated sludge processes, oxidation ponds and aerated lagoons or biological organisms to convert dissolved organic matter to a settleable floc
- Tertiary treatment to remove dissolved organics and inorganics, color, odor, and taste (with foam fractionation, activated carbon, ion exchange, electrodialysis, or ultrafiltration)
- Disposal of high organic containing liquids or solids by combustion (incineration)
- Dewatering of sludge arising from biological systems and solids separation processes with the use of sand beds, vacuum filtration, or centrifugation
- Disposal of sludge by landfill or incineration, or recycling methods.

To determine the optimum wastewater treatment system, there are a number of key factors which should be considered. The EID should demonstrate the analysis and selection method(s) used to arrive at the proposed wastewater treatment design. The following information should be presented:

- Systematic consideration and analysis of all alternative wastewater treatment approaches
- Constituent loadings from various wastewater streams
- System reliability, efficiency, and susceptibility to upset
- Energy and material demands of various treatment systems
- Excess capacity and expandability of system
- BAT for priority and conventional pollutants
- Ability to meet receiving water quality standards.

Solid Wastes

Solid wastes generated at refineries include process sludges, spent catalysts, hazardous wastes, construction debris, and containers. Many solid wastes may contain significant amounts of leachable heavy metals and organics which could contaminate the environment if not treated and disposed of properly.

Therefore, to evaluate the potential impacts from solid wastes, the EID should identify all the solid waste streams. A flow diagram may be provided indicating the generation, collection, transportation, and disposal of these wastes, and present the following information:

- Source, quantity and chemical composition of solid wastes generated
- Proposed measures to handle and dispose of solid wastes, including descriptions of waste management units
- Potential environmental impacts and planned mitigation measures
- Composition of leachates from solid wastes.

Hazardous Wastes

Some wastes generated in refineries are classified as hazardous wastes. The types and volumes vary with the operations. There are refinery source-specific wastes which are currently listed hazardous wastes (K048 to K052) (45 FR 74834, 55 FR 46354) because they contain hazardous constituents such as metals (chromium, copper, nickel, lead, etc.), arsenic, and organic compounds (benzene, toluene, benz(a)anthracene, benzo(a)pyrene, dibenz(a,h)anthracene, etc.). These wastes are:

- Dissolved air flotation float (K048)
- Slop oil emulsion solids (K049)
- Heat exchanger bundle cleaning solids (K050)
- API oil/water separator sludge (K051)
- Leaded tank bottoms (K052)
- Primary oil/water separation sludges (F037, F038).

EPA is currently evaluating several more wastes for listing as hazardous.

Additional information on these wastes can be found in API (1993) and EPA (1982).

Other hazardous wastes that may be found are waste chemicals and compounds used in processes or maintenance activities, which may be RCRA-defined F, U or P wastes. The RCRA mixture rule and derived-from rule affect refinery operations as well. In addition, some items may be hazardous by characteristic or definition, such as certain containers or waste oil. (Olschewsky and Megna 1/4/88). Oil refineries are not RCRA facilities by definition, but, many refineries have obtained RCRA permits for wastewater treatment systems that process hazardous wastewaters.

Hazardous wastes must be managed according to RCRA (or state-equivalent) regulations. Handling and disposal will be separate from other waste management, and the refiner should have a hazardous waste management program to ensure compliance.

Other Wastes

Non-hazardous wastes generated at a refinery include solids and sludges. These wastes are subject to characterization by RCRA requirements, but once determined non-hazardous, may be managed in a variety of ways. Typically, appropriate waste management techniques are applied to each stream in the most cost-effective manner.

Spent catalysts are metallic compound wastes generated by the catalytic cracking units. The volumes are small compared to other waste streams. Catalysts are regenerated in their respective processes, until capacity is severely limited. Catalysts may be reused in a different refinery unit, or recycled to a cement kilns for beneficial reuse of the silica component, when specifications can be met. (Spearman and Zagula 1992)

Sludges are generated throughout the refinery, resulting from processes and from separation in tankage. Sludges with a high percentage liquid are usually filtered or separated. The remaining sludge contains more solids and behaves more like a solid material. The sludge may be used as a fuel if the BTU value is adequate.

Tank bottom sludges accumulate in tanks from the entrained solids settling out of suspension to the bottom. The sludges are removed during infrequent tank cleaning. Refiners have experimented with various methods to minimize the volumes of sludge, but the acid treatment of refinery stocks is almost always highly contaminated with metals and other pollutants.

Sludge accumulating at the bottom of cooling towers generally is adaptable to disposal as fill. However, the removal of the sludge from the tower basin and the transfer of the material to the point of final disposal can pose numerous problems in cleaning, transportation and storage because its high density which does not allow it to flow easily, the need to remove liquids from the sludge, and the need to shut down cooling towers for cleaning. Sludge from water treatment clarification creates the same type of problems.

Sludge or solids from the water treatment softening process is typically a carbonate compound. In some cases it may be reused in the refinery for the neutralization of acid waters or as a coagulant aide in wastewater treatment.

Waste Control and Residuals Disposal

Solid waste volumes and characteristics may be controlled through various measures to concentrate or eliminate the wastes. Refineries have incorporated waste management and waste minimization practices to reduce impacts, process and operational inefficiencies, costs, and future liabilities. These practices are determined on a case-by-case basis.

Wastes may be recycled or reused, particularly when there is inherent value in recycling or reuse. Oily wastes and sludges are typically treated and filtered to recover the oil. The residual solids are then disposed of.

All wastes must be ultimately disposed of, if not reused or recycled. The following are brief descriptions of the disposal options that may be used on site or provided by commercial facilities. The EID should cover the selection of disposal methods to be implemented on site.

The chosen method of disposal for each waste depends on a number of factors, including the volume generated, the economics of material recovery, the disposal capacity available, and disposal costs. Waste disposal options also vary with geographic areas and the current market for wastes.

Landfills

Landfilling has been the most widely used method for disposing of all types of petroleum refinery wastes. The environmental impact of landfilling is contingent not only upon the types and characteristics of generated wastes, but also upon methods of operation and on specific site geologic and climatologic conditions. Landfills are suited to disposal of de-watered solids and sludge from non-hazardous process wastes, construction debris, and trash.

Landfills must meet many regulatory requirements (RCRA or state-equivalent and local) that include proper design and operation, tracking and characterization of wastes, leachate collection and treatment, environmental monitoring and secure closure. Landfills are required to be permitted, so much of the technical data will be provided by the refiner during the permit process. In addition to technical aspects of landfilling, regulatory parameters limit the disposal of organic-containing sludges and residues in landfills by the land disposal regulations (see regulatory section).

A refinery proposing an on-site landfill must meet many criteria for design and operation:

- Selection of a site that is geologically sound, of adequate size to provide substantial capacity, and results in minimal environmental impact
- The routing of surface waters around the landfill site and sloping of cover soil to avoid on-site runoff and erosion
- Characterization and segregation of wastes to prevent mixing of incompatible compounds, such as mixing solids containing heavy metals with acids, or solutions with other wastes which together produce explosions, heat, or noxious gases
- Blending of liquid or semi-liquid wastes with soil or refuse materials to absorb moisture and reduce fluid mobility
- Neutralization of acid and caustic sludges to minimize reactivity
- Providing daily cover of wastes.

Landspreading has historically been used by many refineries. The land disposal regulations have limited the applicability of this disposal option. Landspreading is a relatively inexpensive disposal method, and is typically used for hydrocarbon and organic sludges. Landspreading is also a treatment method, in that lighter components volatilize and heavier organic components biodegrade. Landspreading works best in warm, dry climates.

Landspreading may cause impacts to the environment, depending on how well the method is controlled and managed. Potential impacts are oil contamination of ground and surface waters, accumulation of heavy metals in the underlying soils, and incomplete reduction of organic acids resulting in the generation of intermediate byproducts.

The use of lagoons, ponds, sumps and open pits was a standard liquid and semi-solid waste disposal method for the petroleum refining industry for many years. This method is being phased out for a variety of reasons, including more stringent regulatory requirements addressing groundwater contamination, migratory bird endangerment, and air emissions.

The lagoons, ponds, sumps, and open pits are being replaced with enclosed units such as clarifiers and above- or below-ground tanks. Open pits may still be used for emergency diversion, temporary treatment basins, or evaporation ponds. Ponds or pits may be required to be constructed with liners, leak detection and netting to prevent impacts.

Incineration is a method of disposal of semi-solid and solid organic-containing wastes generated at the refinery. An incinerator must be permitted by regulatory agencies in conformance with the Clean Air Act. The design and operation must meet the regulatory requirements specified in the regulatory section.

Incineration of refinery wastes requires a special type of system to provide adequate detention times, stable combustion temperatures, sufficient mixing, and high heat transfer efficiency. A fluidized bed is one of the few systems that can satisfy all these criteria. A fluidized bed is an incineration system in which inert material (e.g., sand) is supported over a grate. Combustion air is blown through the grate and supports the particles. Waste and supplemental fuel are injected into the bed, where combustion occurs.

The material to be incinerated can be injected either into the fluidized bed or immediately above it. Refinery wastes known to be incinerated by such systems include spent caustic solutions, API separator bottoms, DAF float, biological sludges, and slop oil emulsion solids. Experience has shown that the reaction is self-sustaining if the thermal content of the total wastes incinerated exceeds about 29,000 BTU per gallon. Normal range of operating temperature is from 1,300 to 1,500 °F. Loss of fluidization and plugging of the bed is still a major problem in the operation of these units. Reduced temperatures cause discharge of unburned organics.

Subsurface or deep well injection is a disposal method that originated with the oil and gas extraction industry. Deep well disposal must follow the guidelines established by the Safe Drinking Water Act's Underground Injection Control Program. This program requires injection well operations to be permitted.

Large volume, non-hazardous liquid waste streams are suited to deep well injection (e.g., brines from crude separation). Other wastes that are difficult and expensive to dispose of otherwise may also be injected. Deep well injection program capital and operating costs can be considerable.

Recycling

A liquefied-gas solvent extraction process has been used commercially to remove organic contaminants from refinery sludges. The benefits of the process are that it meets EPA's criteria for BDAT, incorporates recycling, and is less expensive than incineration. The solvent is recovered and recycled to the refinery crude unit, and the non-hazardous solid residue is dewatered and may be disposed of in a landfill. (Chemical Engineering, July 1989)

Other Impacts

Odors

Odors are generated from most of the process and waste materials found in the refinery. Odors will be carried as gases, so the pathways will be those from which air emissions are generated. The impact of offensive odors is of concern where the public may be in contact, near the refinery fence line or beyond. Some odors have an offensive characteristic, particularly those containing sulfur products, such as mercaptans and H_2S. The potential odor problem may be quantified with the air emissions evaluation. Odors may be controlled by air emissions treatment and control.

Odor controls include a good preventive maintenance program; the treatment of H_2S-rich wastewater streams from the catalytic crackers; gas-processing units and vacuum distillation towers; and the flaring of H_2S, mercaptans, other sulfides, and other odor-producing compounds.

Noise

Refinery operations typically generate elevated noise levels, particularly from equipment such as compressors, pumps and flares. Construction activities also generate substantial noise levels. The main impact is on the public, near the refinery fence line.

Because the decibel levels decrease with distance from the noise generation source, refineries may choose to increase distances from the operations locations to the fence line.

The EID should quantify and evaluate the cumulative noise levels, and include the following:

- Identify all noise-sensitive land uses and activities adjoining the refinery site
- Identify existing noise sources, such as automobile and aircraft traffic and other industry near the refinery
- Identify all applicable local noise regulations
- Compare projected noise levels with background noise levels
- Assess the noise impact and propose noise abatement measures.

Coal Gasification Impacts

Coal Extraction

Coal extraction impacts the environment adversely by the alteration of natural habitats, dust generation, and acid mine drainage. Surface mine sites are generally reclaimed after the economic life of the mine is over, mitigating the long-term adverse effects on natural habitats. Dust generation is temporary, and generally not of great significance if attention is paid to its control. Acid runoff from the mine site, the spoils area, and coal storage area is somewhat more problematic. The runoff may have very low pH, and contain suspended and dissolved solids as well as toxic metals. It is generally very difficult to control because of its diverse sources, and can persist long after the mine has shut down. Surface mines also have the potential to disrupt flow of surface and groundwaters.

Regulations under the Clean Water Act require the strict management of mine site runoff to reduce the impacts of low pH waters and the dissolved and suspended matter, sometimes toxic, that results.

Transportation

Facilities that use large quantities of coal are found at or very near a coal mine, near a railroad, or along a large waterway. Using trucks to transport coal over long distances is generally too expensive to be economically feasible. When coal is transported by trucks from the mine to the gasifier, the trucks used are not highway vehicles but very large vehicles specially designed for the movement of coal. They typically run a closed circuit between the mine and the coal storage pile.

Trains are typically loaded by hopper or conveyor at the mine site, travel over a mine-owned spur to a main line, and then over the gasifiers' spur to a specially designed storage/conveyor system where they are emptied (usually through hoppers in car bottoms). Coal is typically loaded and unloaded from barges or ships by conveyor systems that distribute the coal to storage piles or directly to process areas.

The impacts from coal transport by trains and barges are through coal loss at loading and unloading sites, with coal dust generation and spillage along the tracks. Over long periods of time, the amount of coal lost can be substantial, and problems (acid drainage) similar to those of coal pile runoff tend to develop along transport routes. The major impact of trucks operating at a mine site are the fugitive dust emissions from the use of unpaved roads and coal dust generation and coal loss along the route.

Coal Storage On-Site

Once received at the gasifier site, coal is placed either on an active coal pile for use within a week or is placed in an inactive storage pile to be used when the coal supply is interrupted (weather, mine closings, etc.). The active pile, often on a concrete pad, is normally uncovered and monitored visually. Inactive piles are normally not placed on a concrete pad (due to their large size), but are located, as much as possible, in areas where leaching to groundwater is minimized. Inactive piles are generally covered with soil, ash, or other impermeable material to reduce the chance of spontaneous combustion and prevent wetting by rainfall. Some coal piles are monitored with temperature sensors or gas monitors to warn of pile fires.

Waste Storage and Disposal

The majority of wastes at a gasifier site are the ash and slag generated during gasification. These are normally not stored in large quantities at the site. Only about 24 hours' of waste is stored on-site; it is normally quickly shipped to a landfill or to a recycler. However, some wastes may be recycled only during specific seasons (in asphalt manufacturing, for example), and these wastes may be stored long-term on the site. On-site ash storage generates alkaline (rather than acid) runoff, and since ash tends to be dusty, it is often wetted or covered to minimize dust generation.

On-site mines are often used as a disposal site since the ash helps neutralize acid drainage, and it replaces part of the fill material needed to restore the area to the original topography. Landfills off-site are very common, though again the distance cannot be far to be economical. All landfill regulations for nonhazardous wastes or these specific wastes must be observed.

Other large quantity wastes will include occasional catalyst changes and cleaning wastes. These wastes are small in relation to the ash but are large relative to many other sources. Catalysts that contain valuable metals are recycled. Catalysts made of relatively inert materials such as zeolites will normally be disposed of in a landfill or recycled if possible. Cleaning solutions normally require neutralization and filtration prior to discharge to a wastewater treatment plant. However, the cleaning solutions need to be characterized to determine exactly how the material can be treated and how it can be disposed of. Most other wastes generated can be effectively containerized (drums) and disposed of.

Transportation of waste materials may be by train, barge, or by truck. Trucks play a much greater role in the transportation of wastes than in the transportation of coal. Most ash is moved by truck as will the spent catalysts. Hazardous wastes will almost always be transported by truck although some liquid wastes may be sent through the sewer system to a POTW or the plants own wastewater treatment plant.

Products produced by gasifiers include electricity, synthetic natural gas, and a variety of gaseous compounds. Byproducts include sulfur, sulfuric acid, or ammonium sulfate. If electricity is produced, transmission is primarily by above-ground transmission lines. The right-of-way is kept clear with occasional cutting of the brush and grasses. The impact is to break up wooded areas and to create areas of increased erosion on steep hillsides. Environmentally the impacts often are to provide a meadow environment in areas that do not allow such environments to exist long (eastern woodlands). In western states, where trees are not common, the only disruption may be to the area immediately surrounding the transmission towers.

Synthetic natural gas is rarely stored on-site or it is stored in limited quantities in above ground tanks for on-site usage. Any storage of large volumes is normally done by injection into natural underground reservoirs that have been emptied. The gas is normally transported by being pumped into an interstate transmission line, although it may go to a dedicated customer. The impacts are primarily due to the construction of the pipeline. These are temporary disturbances of the environment in which the pipeline traverses. The consequences are normally of short duration in areas that recover rapidly, such as eastern U.S., while desert areas can be impacted for many years. There are minor air pollution impacts from the compressors.

Chemical products such as gases are either pumped directly to the customer or liquified or compressed and stored in large above ground storage tanks. Tanks for storage of compressed or cryogenic gases have very strict construction and maintenance regulations that are followed due to the hazards associated with this type of storage (note the hazard is primarily to workers and the plant and, to a lesser extent, the public). The liquified gases may be transported by rail, truck, or barge while compressed gases are primarily limited to rail transportation

Sulfur can be stored as solid sulfur or as liquid sulfur (if heated). Sulfur storage occurs at all facilities that produce sulfur. The sulfur as produced may contain as much as 10 % H_2S. The storage of sulfur allows the facility to treat the sulfur with catalysts or by other methods to remove the H_2S so that it may be transported. The storage is in specially designed tanks that are normally air tight since the H_2S is collected and returned to the desulfurization equipment. After degassing the sulfur may be stored outside as a solid. The solid is normally hard enough to resist weathering for short periods of time. Liquid sulfur may be shipped by barge, ship, or train. Very rarely can it be shipped by truck as it is difficult to keep it molten for long. Solid sulfur can be shipped by any method.

Sulfuric acid is stored on-site in large steel tanks prior to being shipped. The acid is usually be over 90 % acid (acid below 79 % is more difficult to handle and store). The transportation of the material may be by any mode, but regulations governing its transport are rigid. Accidental spills of the material are very bad on a short-term local basis but it can be neutralized or diluted easily and rapidly. In addition, there is rarely any long-term residual from the spill.

Ammonium sulfate is used as a fertilizer and can be stored and shipped without any special precautions other than prevention of blowing or spillage. Major effects would be to over fertilize land or waterways in the event of a spill. This could lead to reduced dissolved oxygen or algae blooms.

Purification of Crude Gasifier Off-gas

The desired gaseous products of coal gasifiers contain many pollutants that require partial to nearly complete removal prior to practical use of the gas. Depending on gasifier design and mode of operation, some or all of the following pollutants are present:

- Particulates (ash and char)

- Condensable oils, tars and phenols
- Acid gases such as hydrogen sulfide (H_2S), carbonyl sulfide (COS), and CO_2
- Ammonia (NH_3).

Particulate carry-over, when present, includes ash and char, and these are always removed and generally recycled to the gasifier to prevent down-stream processing problems. Particulate carry-over occurs to a greater degree in fluidized bed and entrained flow gasifiers than in moving bed gasifiers, and there are always particulate collection devices in use with the former two types of gasifiers. Cyclones and steel mesh or ceramic filters (for hot gases), or cyclones, baghouses, and hydroclones (for cooled gases) are used to collect the entrained particulates. Recycle of char is desirable so that unburned carbon can be more completely converted to a gaseous product. Recycle of fly ash also results in just one type of ash byproduct rather than two. When the discharged ash is in the form of slag, this ceramic material is relatively non-leachable and it is apt to have value as road base or asphalt aggregate.

Condensable oils, tars, and phenols typically are recovered from moving bed gasifiers and can be handled in several ways. The condensable oils, which are lighter than water, can be used as fuel oil. Tars, if sufficiently clean can also be used as fuel (tars are distinguished from oils by virtue of density greater than water). In the Lurgi process, a "dusty tar" that contains ash is also recovered but this is recycled to the gasifier. Phenols can be recovered and sold as a byproduct.

Sulfur-based gases are derived from all types of gasifiers that use fuels containing sulfur. These must be removed for several reasons. If the sulfur-polluted gases are burned for power generation, the sulfur converts to highly undesirable sulfur dioxide (SO_2). If the product is to be used for production of organic chemicals or SNG, the sulfur could interfere with the required reactions, would possibly poison reaction catalysts, or would result in undesirable impurities in the desired product.

Although nitrogen occurs to a small extent in coal as organic nitrogen compounds, most of the nitrogen is released in elemental form in the fluidized bed and entrained flow gasifiers. However, in moving bed gasifiers, some of the organic nitrogen is converted to ammonia, and this must be removed at an early stage in the gas purification train in order to avoid down-stream problems similar to the ones that sulfur compounds may cause. The usual course of actions is to co-condense ammonia with any oils, tars and phenol, and then separate this mixture in a side-stream operation.

Methods for Desulfurization of Coal Gasification Streams

The amount of sulfur in coal varies by type of coal and by mine site, but most coals contain between 0.5 and 4 % sulfur, and some may have as much as 8.9 % sulfur. The sulfur is usually present as organic sulfur compounds or as iron pyrite (FeS_2), but sulfate salts and elemental sulfur are also found. The sulfur in coal is easily gasified, but sulfur gasification results in hydrogen sulfide (H_2S) and carbonyl sulfide (COS). These are poisonous, reactive, and corrosive gases under most conditions. When burned, H_2S and COS result in SO_2 and to a lesser extent SO_3.

Sulfur must be removed from the gas stream before being emitted to the atmosphere. If the gases are to be used for the production of chemicals or pipeline quality gas, the sulfur compounds must also be removed.

The biggest problem with removing sulfur for the combined cycle coal gasification power plants is that most of the more efficient processes require that the gases be cooled to a relatively low temperature (less than 400 °F) and to near atmospheric pressure. While the energy lost in cooling can be recovered using heat recovery equipment, the system as a whole loses energy efficiency.

There are a large number of processes that are used or have been developed to remove sulfur compounds from gas streams. The majority of these also remove CO_2. The removal of CO_2 is necessary for any chemical usage or pipeline quality gas. For on-site combustion for power, partial CO_2 removal is needed only if the concentrations are high. All sulfur removal processes require that the particulate matter be reduced to an acceptable level first.

Only a limited number of processes are discussed below. Those discussed generally represent a type of process; other processes vary in details, but not the overall nature of the treatment process.

The majority of processes occur in two steps: the first step removes the acid gases from the gasifier stream and the second step regenerates and recycles the absorbent material. There are five major types of processes used: absorption by a solvent, hot carbonate process, physical solvents, hybrid solvents, and direct chemical conversion. The majority of processes use a basic solution of alkanolamines (chemicals with both an alcohol and amine group) to absorb the acid gases. The amine groups react with the chemicals to be removed and the reaction is easily reversible. The solutions that use alkanolamines have the ability to remove CO_2 also since carbon dioxide rapidly forms carbamates with primary and secondary amines. Almost all other methods also use basic solutions which react with the H_2S to form the hydrosulfide ion HS^{-1}. Processes that operate at high pressures also have the capability to remove CO_2 due to its high partial pressure.

A category of "dry bed" processes have been or are being developed to remove sulfur. They are designed to operate in or close to the gasifier's operating conditions and do not require significant cooling or reduction in pressure. These technologies have the potential to greatly increase the overall efficiency of the gasifier when used for electrical production since their use results in less energy loss. Some of these methods use harmless materials in the process (dolomite, iron oxides). Table 3 lists the most commonly used chemicals and some of their properties.

Most processes (see Table 4) remove H_2S from the gasifier stream and produce a concentrated H_2S stream which is sent to a process that converts it to a suitable form. The Claus and Stretford processes are those most commonly used. They produce elemental sulfur, sulfuric acid, and ammonium sulfate. These processes typically recover 90 % of the sulfur. The tail gas still contains about 10 % of the sulfur, a level that may exceed environmental regulations. When this occurs, tail gas cleanup is usually accomplished by other processes, such as the SCOT, which converts (reduces) all sulfur back to the H_2S form and recycles this gas stream back to the upstream conversion process. Using tail gas treatment, sulfur recoveries of 95 to 99.9 % can be achieved.

Waste products from the units are for the most part very limited. Solvents are normally recycled, but a small amount vaporizes. Vaporization is minimized by the facility design and the selection of solvent.

Solid catalysts used normally last 1 to 3 years before replacement. Metallic catalysts can be recycled. Dolomite and salts that are used are generally non-hazardous and are disposed of in landfills or sometimes recycled. The primary concern with the spent materials is the presence of accumulations of trace quantities of chemicals over long periods of time. Chemicals such as cyanides, arsenic, and lead can accumulate.

Criteria for selection of a particular process is too involved to discuss in this section. However, there are limitations on concentrations of the various chemicals that enter the units (Claus needs H_2S at 30 % or greater concentration, while Stretford and Unisulf operate at less than 10 %; MEA is destroyed by HCN), the temperatures and pressures at which a unit operates, considerations as to what utilities are needed (water, electricity), other environmental considerations (e.g., arsenic-based units are generally not used in the U.S. but are found in Europe). The units selected are chosen to meet all conditions found at the site, meet all regulations, and also to be as economical as possible.

TABLE 5. CHEMICALS USED FOR ACID GAS CLEANUP

Chemical	Product	Comments
MEA—monoethanolamine	H_2S	Removes CO_2; Degraded by HCN, O_2, COS, CS_2
DEA—diethanolamine	H_2S	Similar to MEA, not degraded by COS
TEA—triethanolamine	H_2S	
DIPA—diisopropanolamine	H_2S	Used in SCOT process and many hybrid solvents
DGA—diglycolamine	H_2S	Operates at high concentrations (low operating costs)
MDEA—methyldiethanolamine	H_2S	A good selective solvent, can be used for CO_2 removal, low capital and energy costs
SELEXOL—dimethylether of polyethylene glycol	H_2S	Removes H_2S, CO_2, HCN, NH_3, COS, CS_2
Purisol—N-methyl 2-pyrrolidone	H_2S	Removes H_2S, CO_2, HCN, NH_3, COS, CS_2
Rectisol—methanol	H_2S	Removes H_2S, CO_2, HCN, NH_3, COS, CS_2
Fe_2O_3	S, SO_2	A direct chemical conversion process
$CaCO_3MgO$	H_2S	Difficult to regenerate
K_2CO_3	H_2S	Used for CO_2 removal
V^{+5} & ADA (anthraquinone-disulfonic acid)	S	A direct chemical conversion process
Fe^{+3}	S	Several wet and dry direct conversion processes based on this
NQ—(naphtoquinone) + NaHS + $NaHCO_3$	S	NQ is an oxygen carrier
KH_2AsO_3 + KH_2AsO_4	S	(Thylox process dates back to 1929)
SO_2	S	Basic Claus reaction
$CuSO_4$ (Cu^{+2})	H_2SO_4	

TABLE 6. ACID GAS CLEANUP TECHNOLOGIES

Acid Gas Removal					
Process	**Process Type**	**Removes**	**Product**	**Comment**	**Licensor**
Benfield	Hot carbonate	CO_2, H_2S, COS		Preferred as a CO_2 removal process	Union Carbide
CataCarb	potassium salt solution	CO_2, H_2S, COS		Preferred as a CO_2 removal process	Eichmeyer & Associates
Rectisol	methanol	CO_2, H_2S, COS, N_2	CO_2, H_2, N_2	Physical solvent	Linde AG, Linde GmbH
Selexol	dimethyl ether or polyethylene glycol	H_2S, CO_2		highly selective physical solvent for H_2S	Norton Co./ Allied Chemical
Sepasolv MPE				physical solvent good for COS and mercaptan removal	BASF Aktiengesellschaft
Sulfint	Uses venturi scrubber and a chelated iron for reduction to S	H_2S	S	all other sulfur compounds present are released	Integral Engineering
Flexsorb HP	K^+ salt and hindered amine	CO_2	CO_2	The hybrid solvent gives good CO_2 carring capacity	Exxon
DELSEP membrane	membrane separation	H_2S, CO_2		high conc. H_2S may need cleanup	Enstar Engineering
Lo-Cat	regenerable oxidized iron	H_2S	S	H_2S specific operates to 150 psig	ARI Technologies
GAS/SPEC ST1	MDEA	H_2S, CO_2	H_2S	Can be used to remove CO_2 from low sulfur streams	Dow

Table 6. ACID GAS CLEANUP TECHNOLOGIES (CONTINUED)

Acid Gas Desulfurization					
Process	**Process Type**	**Removes**	**Product**	**Comment**	**Licensor**
Claus	partial oxidation/ catalysis	H_2S, SO_2	S	> 30 % H_2S, can also be used to destroy NH_3	
MCRC sulfur recovery		H_2S	S	Uses 3 or more reactors that switch roles during regeneration of catalyst	Enstar Engineering, Mineral & Chemical Resource Co.
Stretford	vanadium salt and ADA	H_2S	S	H_2S less than 10 %	British Gas Corp.
TAKAHAX	NQ + NaHS + $NaHCO_3$	H_2S	S	Similar to Stretford but sulfur removed from bottom as sludge	Tokyo Gas Corp.

Table 6. ACID GAS CLEANUP TECHNOLOGIES (CONTINUED)

Tail Gas Cleanup

Process	Process Type	Removes	Product	Comment	Licensor
SCOT (Shell Claus Offgas Treating)	Catalytic conversion to H_2S, alkanoamine (DIPA) recycle back to Claus process	H_2S, COS, SO_2	H_2S	Commonly used after Claus, recycles back to Claus	Shell
Beavon Sulfur Removal Process (BSRP)	Fuel gas and cobalt molybdate catalyst to reduce to H_2S	H_2S, COS, SO_2	H_2S	Has not been demonstrated with high CO_2 tail gases, uses MDEA	Union Oil CA., R.M. Parsons
BSRP-Selectox	Selectox catalyst	H_2S, COS, SO_2	S	good on lean tail gases (5% or less), a dry process	Union Oil CA., R.M. Parsons
Cleanair	Similar to Stretford	H_2S, SO_2	S	3 stages one each for SO_2, H_2S, and COS & CS_2	J.F. Pritchard Co.
Sulften	uses hydrolysis and hydro-genation to convert to H_2S absorbed with MDEA	H_2S, SO_2	H_2S	Discharges as low as 10 ppm H_2S	Ford, Bacon & Davis, Union Carbide
IFP	Claus catalyzed in a alkaline earth metal salt of carboxylic acid	H_2S, COS, CS_2, SO_2	S	CS_2 and COS are converted to SO_2 in a furnace, uses NH_3 as an absorbent	Institut Francais du Petrole
Sulfreen	Similar to Claus	H_2S, SO_2	S	Low temp (260-300°F); multiple beds with on/off cycles	Lurgi Gesellshaft
TDP Aqua Claus	Claus reaction in aqueous phase	H_2S, SO_2	S	Reacted is sodium phosphite solution	Stauffer Chemical
Unisulf		H_2S	S	for <10% H_2S, similar to Stretford	Union Oil Ca., Parsons

9. OTHER ISSUES

Consultation and Coordination

Each of the many laws, regulations, executive orders, and policies identified in the Regulatory Overview section of this guidance document should be addressed in the consultation and coordination section of an EIS. The applicant should provide a record of their activities and actions under each of the initiatives. The applicant provided environmental setting and environmental consequences materials should include sufficient data on the environment issues raised by these laws, regulations, and orders to identify and analyze the potential impacts.

List of Preparers

The guidelines are specific that all parties, whether EPA, consultant, or applicant, that are preparers of portions of the EIS or background papers or conducted analyses that are included in these documents should be listed along with their qualifications and designated responsibility in the documents.

References

All parties preparing background papers or sections of the EIS must document their personal communications and references cited rigorously using a recognized publishing standard agreed to and used by all the EIS contributors. The applicant and EPA must be clear on the level of source documentation. There should be no question on the source of data, kinds of analysis, quality of field data, etc. that are used and recorded in the EIS.

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