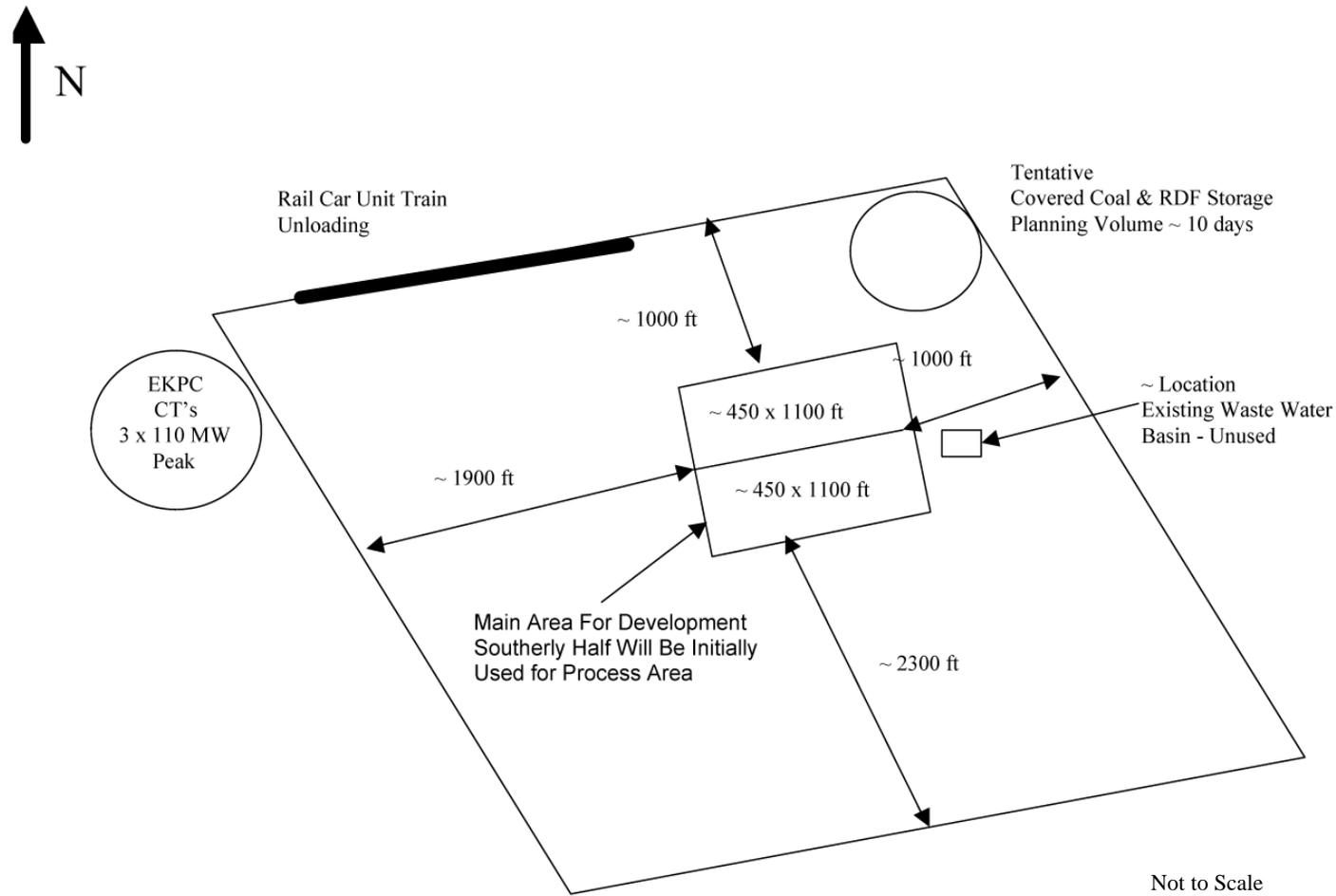


Source: EIV 2000.



Figure 3.1-7. Topographic Map of the Project Site



**Figure 3.1-8.** Generalized Rail Loop Layout for Kentucky Pioneer IGCC Demonstration Project Facility

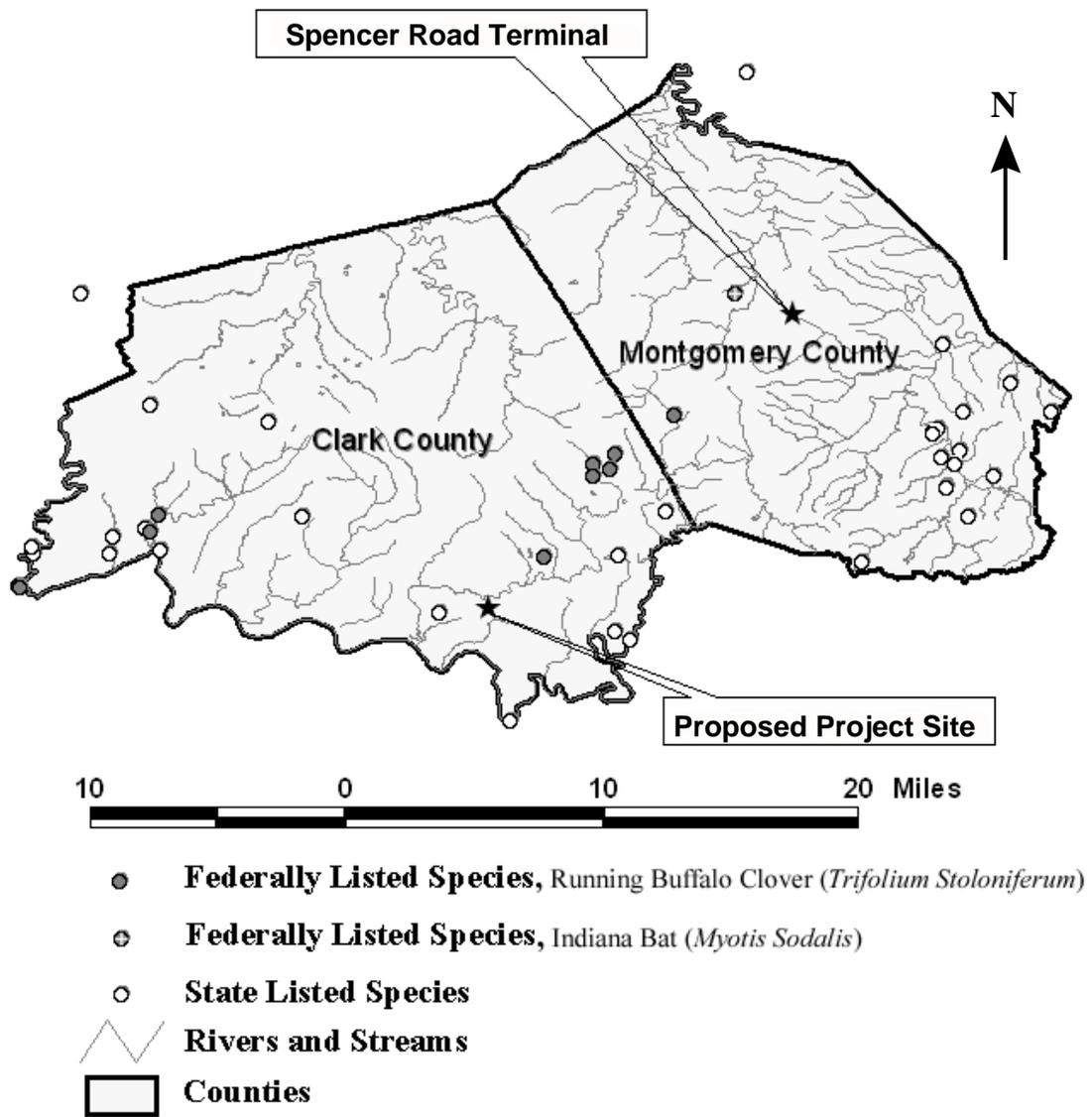


Figure 3.1-9. Spencer Road Terminal and Sensitive Areas in Clark and Montgomery Counties

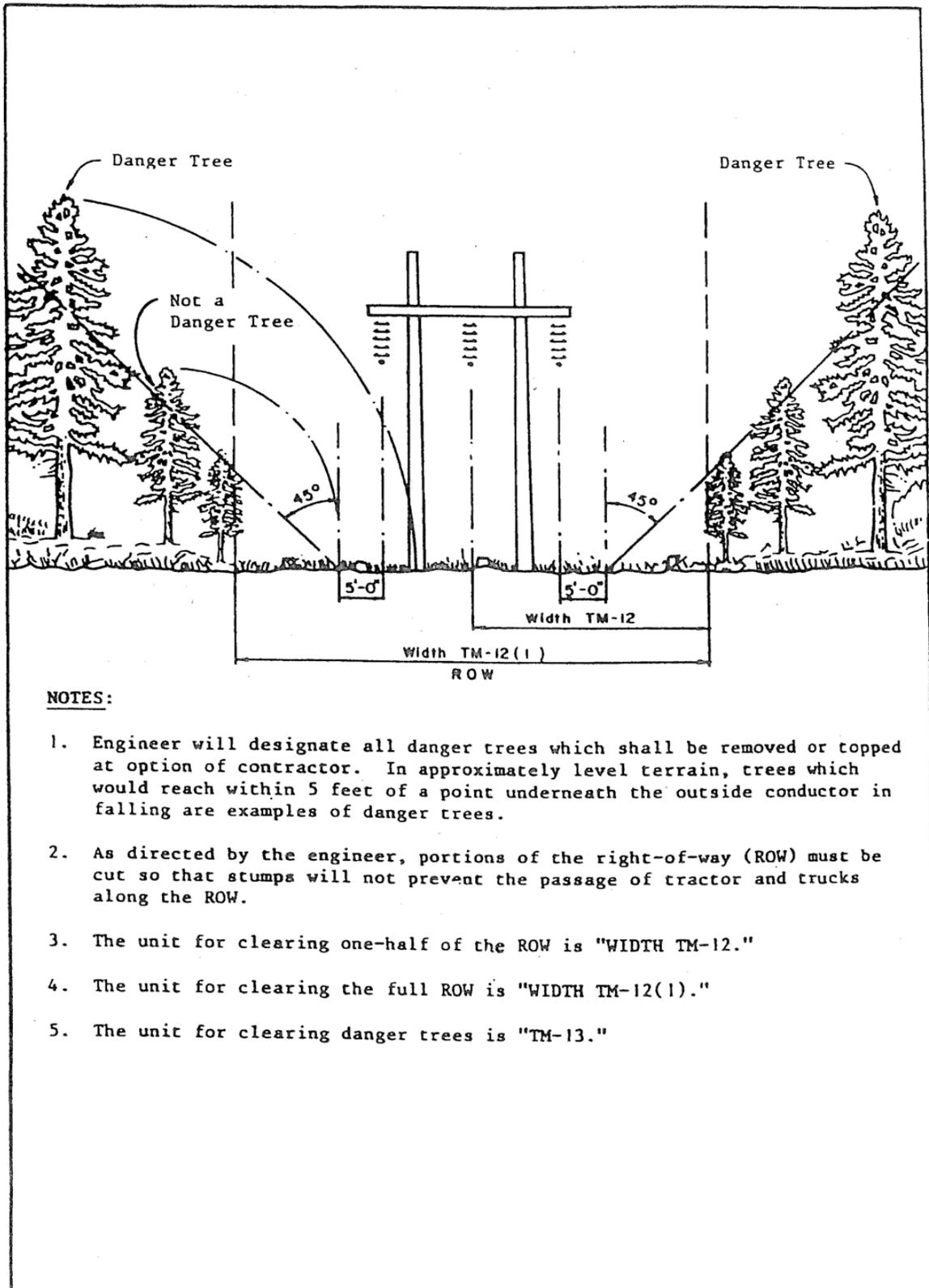


Figure 3.1-10. Typical East Kentucky Power Cooperative 138-kV Transmission Line

As stated previously, the exact route of the transmission line is yet to be determined. The U.S. Department of Agriculture's Rural Utility Service (RUS) has approval authority for this capacity upgrade (Global Energy 2000b). Under RUS *National Environmental Policy Act* (NEPA) policies and procedures, transmission lines of less than 230 kV and less than 40.2 kilometers (25 miles) may be categorically excluded from the requirement to prepare an EIS under NEPA. Transmission lines in this category normally require an Environmental Report (ER) for the application to be approved (7 CFR 1794.22).

The direct-line distance between the proposed station location and the Spencer Road Terminal is 24 kilometers (14.9 miles). The proposed 138-kV transmission line is 27 kilometers (17 miles) in length, therefore the proposed route would only deviate to either side of the direct line between the two locations by a maximum of 1.6 kilometers (1 mile). This establishes a 3.2-kilometer-wide (2-mile-wide) corridor between the proposed site location and the Spencer Road Terminal into which the route must fit. The transmission line should follow existing routes to the greatest extent practicable. The terrain in this corridor is typified by gently rolling hills and land use is predominantly agricultural, with a few small areas of mixed woodland and agricultural land. There are very few residences along the proposed route as it runs through areas classified as rural. The geology in this area is similar to that found at the project location, as described in Section 4.6, Geology.

The proposed route may cross between approximately five and ten creeks and streams, as shown in Figure 3.1-9. Many of these streams are intermittent and ephemeral and would not be directly affected by construction of the transmission line. Cultural resources, such as historic sites and structures, may also be encountered along the route. The typical construction procedures that would be implemented would minimize impacts to these resources by avoiding the locations during route planning. Intermittent and ephemeral streams are typically crossed during periods of no recorded flow. Impacts to streams would most likely be minor should a flow be present during construction, since the line would pass over the creek or stream.

As Figure 3.1-9 shows, there are seven locations along or near the area which would contain the transmission line route where federally-listed endangered species have been shown to occur. Six of these seven locations represent the presence of the endangered plant, running buffalo clover (*Trifolium stoloniferum*), with the seventh, located to the northeast of the Spencer Road Terminal, representing the presence of the endangered mammal, the Indiana bat (*Myotis sodalis*). To prevent any impacts to these endangered species and their habitat, the route would be established to avoid these locations and could be constructed underground, if necessary. If construction were required near the location of the Indiana bat habitat, special procedures would be required. Any required tree removal could only occur during the bat's hibernation period, which occurs between November 15<sup>th</sup> and March 31<sup>st</sup>.

The transmission line would be constructed to support the power island combined cycle units regardless of approval of the Proposed Action. Therefore, it is considered a related action for both No Action Alternative 2 and the Proposed Action.

### **3.1.1 Kentucky Pioneer IGCC Demonstration Project Facility Description**

The Kentucky Pioneer IGCC Demonstration Project facility would be located on a 121-hectare (300-acre) tract within the 1,263-hectare (3,120-acre) J.K. Smith Site. The facility would demonstrate the following innovative technologies: (1) gasification of a blend of coal and refuse derived fuel (RDF) pellets; and (2) the utilization of a synthesis gas (syngas) product as a clean fuel in combined cycle turbine generator sets. The project would be a commercial operation, and is expected to be active for at least 20 years.

The total cost of the Kentucky Pioneer IGCC Demonstration Project is currently estimated to be \$414 million. Kentucky Pioneer Energy, LLC (KPE), has indicated that approximately 80 percent (\$331.2 million) of the project cost is allocated for the construction and operation of the British Gas Lurgi (BGL) Process facility demonstration portions of the project. The proposed federal action is for DOE to provide, through

a Cooperative Agreement with KPE, a subsidiary of Global Energy, Inc., approximately \$60 million (approximately 15 percent of overall \$414 million project cost) in cost-shared funding support for the design, construction, and operation of the proposed demonstration facilities.

Figure 3.1.1-1 presents a conceptualized layout and process flow of the complete Kentucky Pioneer IGCC Demonstration Project facility. To facilitate discussion of the project, the layout has been divided into the following two parts: (1) the combined cycle units, or power island; and (2) the BGL process demonstration, or gasification island.

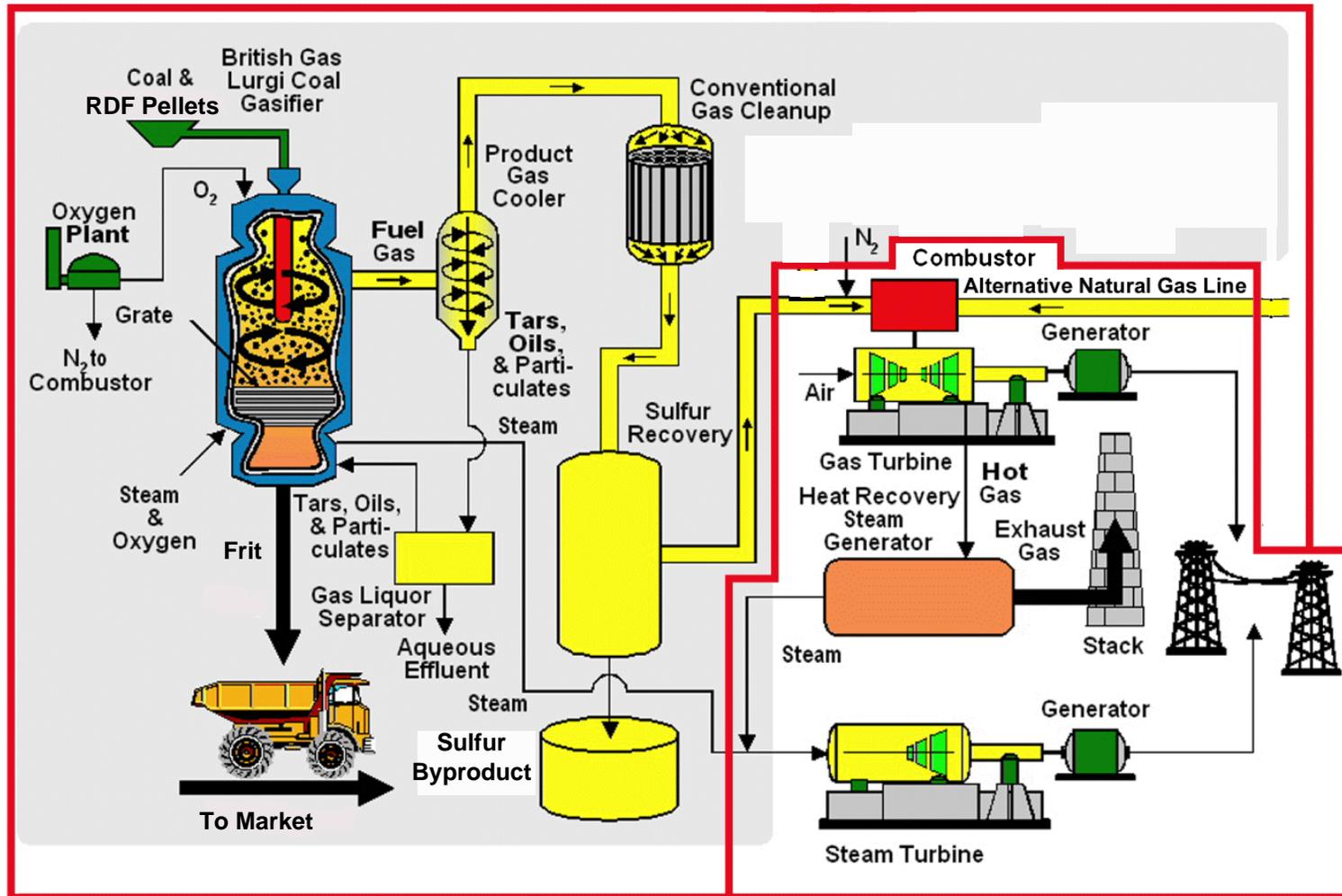
The estimated project cost of the power island would be \$86.4 million. The primary power production area would consist of two General Electric (GE) 7FA CTs coupled to a Heat Recovery Steam Generator. The GE 7FA CT is a heavy duty, industrial type machine with high efficiency and low nitrogen oxide (NO<sub>x</sub>) and carbon monoxide (CO) emissions. F-Frame turbines are single-casing, single-shaft machines with a common rotor. The turbine sits on a horizontal axis with the cold end (compressor end) attached to the generator. The turbines have axial exhaust for improved efficiency. The F-Frame combustion turbine can attain 100 percent power load within 30 minutes and generate about 197 megawatts (MW). The Heat Recovery Steam Generator is coupled to the GE 7FA turbine and utilizes the hot exhaust to create steam. This steam then drives another turbine to create an additional 93 MW of electricity, thus improving the efficiency of the fuel source over conventional turbine generation methods. The two-unit facility is designed to generate 580 MW of gross electricity, of which approximately 40 MW would be used to operate the facility. Thus, it would produce a net power output of 540 MW. The turbines would be fired with natural gas under No Action Alternative 2 and with syngas fuel should the Proposed Action proceed. Under the Proposed Action, the turbines would operate on natural gas only if the gasifiers would be taken off line for maintenance. Natural gas is available as a fuel supply from an existing EKPC supply line and can alternatively be supplied, if necessary, from several nearby transmission pipelines (EIV 2000).

The Proposed Action is to provide cost-shared funding for the construction and operation of the power and gasification islands. The proposed project would consist of the following major facility components: (1) RDF pellet and coal receipt and storage sheds; (2) gasification plant; (3) sulfur removal and recovery facility; (4) air separation plant; and (5) two combined cycle power units. The production of syngas in the BGL process occurs in the gasification plant and utilizes the sulfur removal and recovery facility and air separation plant.

Under the Proposed Action, the combined cycle turbines would be fired with syngas. The syngas firing process consists of the following four steps: (1) generation of syngas from RDF pellets and coal reacting with steam and oxygen in a high temperature reducing atmosphere; (2) removal of contaminants, including particulates and sulfur in the sulfur removal and recovery facility; (3) clean syngas combustion in a gas turbine generator to produce electricity; and (4) recovery of residual heat in the hot exhaust gas produced by the gas turbine. The residual heat is used to generate steam in a heat recovery steam generator that produces additional electricity in a steam turbine, which is the combined cycle aspect of the plant.

KPE will not begin detailed design of the proposed project, including layout and flowsheet information, until the project financing is finalized. However, KPE has provided rough general estimates of quantities of materials required for the construction of the gasification island facilities. The estimates are as follows: steel - 160,000 tons; concrete - 145,000 tons; pipe - 140,000 tons; and wire - 100,000 tons. Figure 3.1.1-2 identifies a conceptual facility layout depicting the major process elements of the project.

“Gasification Island” - BGL Process



Source: NETL 2001.

“Power Island” - Combined Cycle Units

Figure 3.1.1-1. Concept Layout and Process Flow of the Kentucky Pioneer IGCC Demonstration Project Facility

### **3.1.2 Kentucky Pioneer IGCC Demonstration Project Process Description**

The following subsections describe the facility and project processes. Figure 3.1.1-1 provides a process flow diagram for the Kentucky Pioneer IGCC Demonstration Project.

#### **3.1.2.1 Raw Material Receipt, Storage, and Preparation**

The primary raw materials used in the BGL gasification process would be high-sulfur coal, RDF pellets manufactured from municipal solid waste (MSW), limestone, and petroleum coke. The RDF pellets and high-sulfur coal would be received at the project facility by railcar from offsite. RDF pellets would be shipped in covered cars or closed containers. They would be unloaded in an enclosed concrete-floored environment containing electric feed conveying equipment in accordance with the Final PSD/Title V Air Permit obtained by KPE on June 7, 2001. This equipment would move the material into the covered storage area, which would be enclosed and concrete contained. A single building or enclosure is envisioned for storage of both RDF pellets and coal. Dust control would be integral to the enclosed unloading and handling system and conform to air permit emission limits in the Final PSD/Title V Air Permit. Receiving, storage, and handling systems would be covered and weather protected to avoid precipitation and runoff management concerns.

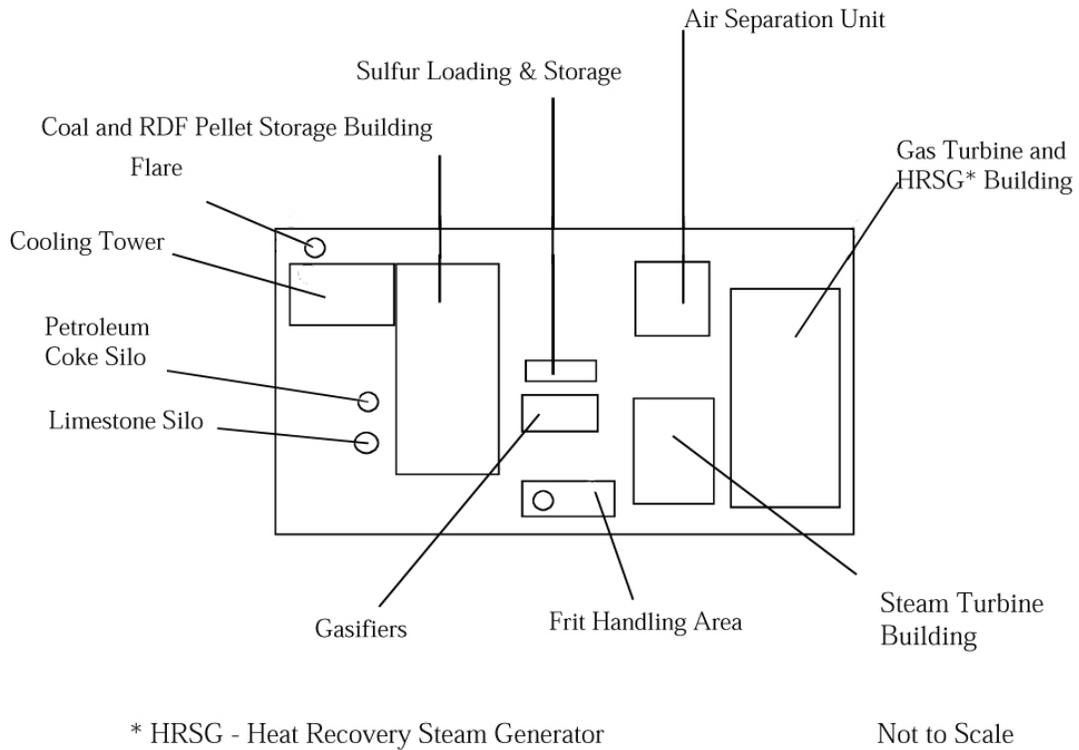
The storage building would be sized to house approximately a 10-day supply of coal and RDF pellets (Global Energy 2000b). The building would be located within the 121-hectare (300-acre) project site. Limestone would also be received by railcar and stored in silos onsite. Each of the silos would have a storage capacity of 272 metric tons (300 tons). RDF pellets, coal, and limestone would be transported from the single building and silos to the gasifier by covered conveyers to ensure a high level of control of particulate emissions. During the demonstration period, the facility would use a co-feed of RDF pellets and high-sulfur coal at a 1:1 ratio. To operate the facility, approximately 745,022 metric tons per year (821,250 tons per year) each of RDF pellets and coal would be required (EIV 2000).

#### **3.1.2.2 Continuous Gasification Process**

This section describes the three stages comprising the continuous gasification process. The air separation process, BGL gasification, and sulfur removal and recovery would all occur concurrently during the gasification process; however, each stage occurs in a separate facility. This section describes each stage and facility separately to develop an understanding of the process and is not intended for use as a chronological sequence description of the gasification process.

##### ***Air Separation Process***

The purpose of the air separation plant is to extract oxygen (O<sub>2</sub>) and N<sub>2</sub> from the atmosphere for use in the gasification process. An on-site air separation unit would supply approximately 1,814.4 metric tons (2,000 tons) per day (TPD) of O<sub>2</sub> to the gasifiers. The air separation unit will also supply N<sub>2</sub> for the dilution of fuel gas before it is used in the gas turbines. The air separation unit uses electricity generated by the facility to satisfy its energy needs and has no direct emissions. The air separation plant would use either cryogenic or pressure swing processes to purify air from the atmosphere through a series of separation steps.



Source: EIV 2000.

**Figure 3.1.1-2.** Kentucky Pioneer IGCC Demonstration Project Facility Conceptual Layout

## **BGL Gasification**

The gasification process occurs in four BGL gasifiers which are fixed-bed, oxygen-blown slagging gasifiers that operate at a pressure of approximately 350 to 450 pounds per square inch-gauge and have a temperature range of as high as 1,982 degrees Celsius ( $^{\circ}\text{C}$ ) (3,600 degrees Fahrenheit [ $^{\circ}\text{F}$ ]) in the lower section of the reactor to approximately 482 $^{\circ}\text{C}$  (900 $^{\circ}\text{F}$ ) in the upper section of the reactor. A syngas is produced from the high temperature and low oxygen environment in the reactor which causes the decomposition of the feed into its basic elements. The BGL gasification process is a pressurized, closed process that has no emissions or stack. However, in case of a malfunction, the gasifiers would be routed to an emergency flare. Petroleum coke would be used for the cold startups of the gasifiers. Approximately 54 metric tons (60 tons) of petroleum coke would be required for each of the four BGL gasifier units. KPE has indicated that once initial start-up fills are complete, further quantities of petroleum coke would be put into the storage facility for future use, when necessary. Limestone is a required component of the gasification process, comprising of approximately 2 to 3 percent of overall material feed. At the fuel feed rates proposed, approximately 127 metric tons (140 tons) of limestone would be required per day of operation.

Gasification is a process for converting materials, or, for the purposes of the Kentucky Pioneer IGCC Demonstration Project, the high-sulfur coal and RDF pellet co-feed, into syngas fuel. The composition of syngas is 55 percent carbon monoxide (CO), 30 percent hydrogen (H<sub>2</sub>), 10 percent carbon dioxide (CO<sub>2</sub>), and 5 percent methane and ethane. Sulfur-cleaning processes discussed in the following section reduce the sulfur component of the syngas to a maximum of 40 parts per million of hydrogen sulfide (H<sub>2</sub>S). The process is different from incineration, which completely oxidizes carbon bearing materials to CO<sub>2</sub>, does not allow for the recycling of materials within the system, and has low energy or heat recovery options.

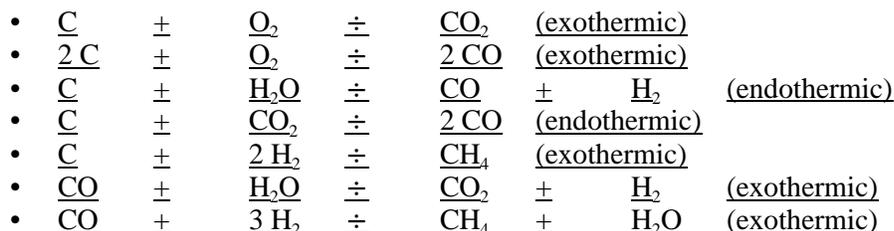
Each pressurized reaction vessel, or BGL gasifier, is a long vertical tube filled with a bed of high carbon content feed material, in this case coal and RDF pellets, that is converted to syngas by the reactions occurring within the vessel. The bed of coal and RDF pellets is consumed and converted to syngas primarily at the lower level of the gasifier. The carbon content feed material is fed into the vessel through a series of feed lock hoppers, lock valves, and level gauges located near the top of the gasifier. The individual pieces of coal and RDF descend down the vertical tube in a continual stream, ultimately reaching the bottom of the gasifier, where they are consumed. Though individual pieces of coal and RDF constantly descend during gasifier operation, the column of materials is kept at a fixed height due to the system design of the feed. The constant height of the column is why each unit is called a “fixed bed” slagging gasifier.

The gasifier itself is water jacketed and lined internally with a high-temperature refractory brick. This allows for substantial thermal insulation within the unit and minimizes heat loss through the walls of the unit. This results in maximizing the thermal efficiency of the gasification process in that approximately 92 percent of the calorific, or heat, value of the coal and RDF pellets is converted to calorific value of the syngas.

At the bottom of each gasifier unit, the inner diameter narrows to form the taphole for removal of molten vitreous frit material. This narrowing of the inner diameter is sufficient to support the column of descending feed material. At the bottom of the unit, just above the narrowing of the taphole, are injection ports, also called tuyeres, for the introduction of high purity O<sub>2</sub>, high pressure steam, and the reinjection feed for particulates, tars, oils, and other hydrocarbons removed from the raw syngas later in the process. As previously stated, the gasifier is operated at a pressure of approximately 350 to 450 pounds per square inch-gauge, though higher pressures and correspondingly higher throughput rates are possible.

Slagging fixed-bed gasification, used in the BGL process, is a thermodynamically driven chemical conversion process occurring in a stoichiometrically, or carefully, controlled environment that converts a carbon content feed material to syngas. The chemical reactions take place at high temperatures, ranging from 1,538 to 1,982 $^{\circ}\text{C}$  (2,800 to 3,600 $^{\circ}\text{F}$ ), in the presence of steam, and in a low-O<sub>2</sub>, chemically reducing atmosphere within the gasifier. Incineration and combustion typically occur in O<sub>2</sub>-rich, chemically oxidizing, and non-stoichiometrically controlled environments.

Gasification involves a complex set of reactions and equilibria established within the BGL gasifier. Some of the simplified reactions that take place within the gasifier are as follows:



The exothermic reactions, as written, generate heat, while the endothermic reactions require heat input to occur as written. The stoichiometric balance of these reactions within the gasifier results in the formation of syngas that retains a substantial portion of the calorific value of the coal and RDF pellet inputs.

These reactions occur very rapidly, particularly at the temperatures established in the gasifier; however, the rates of reaction do vary. The first two reactions listed, the conversion of carbon and oxygen gas into  $\text{CO}_2$  and  $\text{CO}$ , are the fastest to occur and take place almost instantaneously at the point of introduction of the  $\text{O}_2$  and steam at the tuyeres. This localized area within the gasifier is referred to as the partial oxidation zone and is the area where traditional oxidation takes place. The coal and RDF are converted to  $\text{CO}$ ,  $\text{CO}_2$ , and water via oxidation. A significantly higher temperature is generated in the gasifier than is possible in a conventional air-blown incinerator due to the use of pure  $\text{O}_2$ . The minimum temperature in this zone is expected to be over  $1,538^\circ\text{C}$  ( $2,800^\circ\text{F}$ ), with actual temperatures ranging from  $1,650$  to  $1,982^\circ\text{C}$  ( $3,000$  to  $3,600^\circ\text{F}$ ). Conventional incinerators operate at a maximum temperature below  $1,427^\circ\text{C}$  ( $2,600^\circ\text{F}$ ) and normal operating temperatures typically range from  $1,150$  to  $1,316^\circ\text{C}$  ( $2,100$  to  $2,400^\circ\text{F}$ ). This significant difference in temperatures allows for increased destruction efficiency of complicated organic materials. The use of  $\text{O}_2$  rather than air results in a major volume reduction for the raw syngas as compared to the stack emissions of a traditional incinerator, which also reduced the costs of downstream gas purification for the raw syngas.

The  $\text{O}_2$  is almost instantaneously consumed in the partial oxidation zone, down to part per million levels, and as a result, the atmosphere within the BGL gasifier is converted to a high-temperature reducing environment, called the reducing zone. The heat released from the first two reactions then becomes sufficient to provide the necessary energy for the remaining five reactions, which are the primary gasification reactions, to proceed rapidly and generate the syngas. The reducing zone begins immediately above the limited oxidation zone and the point of introduction for the  $\text{O}_2$ . In the reducing zone, the  $\text{O}_2$  has been completely consumed. The injected steam and the water vapor produced from the above reactions comes in contact with the incandescent carbon bed, forming  $\text{H}_2$ ,  $\text{CO}$ , and some methane ( $\text{CH}_4$ ) and  $\text{CO}_2$ , and acts as a powerful reducing medium. The temperature of this zone varies from the hearth temperature of  $1,982^\circ\text{C}$  ( $3,600^\circ\text{F}$ ) to greater than  $1,316^\circ\text{C}$  ( $2,400^\circ\text{F}$ ) approximately 1.2 meters (4.0 feet) above the introduction point of the  $\text{O}_2$ . This harsh reducing atmosphere is present in the gasifier throughout operation and provides for long residence times at high temperatures, ensuring complete breakdown of the RDF pellets and the reinjection stream of particulates, tars, oils, and other hydrocarbons fed into the unit.

Complicated organic materials, including polychlorinated biphenyls, trichlorobenzenes, polychlorinated dibenzodioxins, furans, perchloroethylene, and other industrial waste materials would also be broken down through the combination of high-temperature oxidation followed immediately by high-temperature reduction. The conditions present would be sufficient to break strong chemical ionic bonds, including the diatomic chlorine and carbon chlorine bonds. Dioxins, furans, and other recombination products would not exist as anything more than transient species at the temperatures present in the oxidation zone. Any formation of such materials in the oxidation zone would be completely broken down in the atmosphere within the reduction zone. The reducing zone also prevents formation of oxidized sulfur and nitrogen species such as  $\text{SO}_2$  and  $\text{NO}_x$ . Sulfur is primarily converted to  $\text{H}_2\text{S}$  and, to a lesser degree, carbonyl sulfide ( $\text{COS}$ ), while nitrogen is converted to diatomic nitrogen gas ( $\text{N}_2$ ) and ammonia, with trace amounts

of hydrogen cyanide also present. Halogens, such as chlorine, are converted to their corresponding hydrogen halides rather than diatomic halogen, i.e., hydrogen chloride rather than chlorine gas. The reduced species, including H<sub>2</sub>S, COS, ammonia, hydrogen cyanide, and hydrogen chloride, are easily and virtually completely removed from the raw syngas while it passes through the clean-up phase.

As the hot syngas rises from the partial oxidation zone at the bottom of the gasifier, through the reducing zone and higher within the unit, in a path opposite to the descending coal and RDF pellet feed stream, the syngas transfers some of its heat energy to the descending solid material. This cools the syngas to a temperature of approximately 427 to 538°C (800 to 1,000°F). Once this occurs, no additional reactions can take place in the reducing atmosphere and the syngas exits the gasifier where it is immediately quenched with water and begins the clean-up process. The transfer of heat from the raw syngas to the descending column of feed materials preheats the material, thus conserving energy and improving the overall efficiency of the system. As the feed materials heat up, water and low boiling organic materials are driven off. As the temperature of the material continues to rise, volatile oils and tars are driven off via a distillation and entrainment mechanism. The water, light hydrocarbons, oils and tars exit the unit with the raw syngas and are condensed and removed from the raw syngas by the downstream water quench and gas cooling units located within the cooling tower. Steam is also produced as the syngas enters the cooling tower as the syngas is cooled and purified by heat exchange. The conceptual process flow provided by KPE assumes a circulation rate of 75,000 liters (20,000 gallons) per minute within the tower. The organic liquid, oils, and tars are separated from the quench water and recycled back to the gasifier to undergo further conversion into syngas. This injection occurs via the O<sub>2</sub> and steam injection tuyeres at the bottom of the unit.

Though this process of driving off volatile matter is similar to the process by which charcoal is created, it is only a coincidental result of the process and not the ultimate pathway. Charcoal production is conducted at low temperatures in the relative absence of O<sub>2</sub> and results in a 25 to 30 percent yield of the original material and the potential for large waste streams, including air emissions. This portion of the BGL process differs because the condensed organic materials are captured and recycled back into the gasifier for complete conversion into syngas. These condensed materials are not considered a waste stream and there are no potential emissions of material to the environment.

This process is what differentiates BGL gasification from other gasifier technologies. Other methods of gasification, including entrained flow and slurry feed, only allow for one pass of all feed materials through the gasifier for conversion into syngas. The one-pass method results in lower thermal efficiencies since the feed material is not preheated, nor is the raw syngas cooled before it leaves the gasifier unit. The volatilization of oils and tars in the BGL process represents only a small portion of the feed material, yet it greatly increases the thermal efficiency of the BGL process in comparison to other gasification techniques, and the tars and oils are reinjected into the unit for conversion into syngas. The volatilization of oils and tars in the BGL unit occurs in the complete absence of O<sub>2</sub> and in a reducing environment, which eliminates the possibility of recombination reactions to form hazardous chemicals such as dioxins and furans. In the unlikely event that such chemicals were created, they would be condensed out in the water quench and downstream cleanup and ultimately be reinjected back into the unit (Vick 2001).

Along with the volatilization of tars and oils at the top of the feed column, high volatility metals come off of the feed and leave the gasifier unit with the raw syngas, while the low volatility metals continue descending with the feed column through the unit. Table 3.1-1 shows the partitioning percentage of each metal retained in the feed column and that comes off the feed column with the raw syngas. The metals that leave with the raw syngas form into metal sulfide solids, due to the chemical interaction with the sulfur in the raw syngas, in the downstream gas clean-up process. In the clean-up process, the tar and oil condensate stream is cooled to about 38°C (100°F), which ensures extensive condensation of the metals. These downstream metal solids are reinjected with the tar and oil feed through the tuyeres and the metals are ultimately retained in the glassy silica matrix of the vitreous frit. Limited quantities of the metals are retained in the process water of the quench water, as shown in Table 3.1-1. This water is separated from the tar and oil condensate reinjection feed and reused in the quench to provide further opportunity for retention of metals within the system (Global Energy 2001a).

**Table 3.1-1. Metals Partitioning in a Typical Gasification System**

	<u>Metals</u>	<u>Vitreous Frit</u>	<u>Downstream Solids</u>	<u>Process Water</u>
<b><u>Low Volatility Metals</u></b>	<u>Cobalt</u>	<u>90%</u>	<u>10%</u>	<u>0%</u>
	<u>Copper</u>	<u>71%</u>	<u>29%</u>	<u>&lt;0.3%</u>
	<u>Manganese</u>	<u>87%</u>	<u>8%</u>	<u>5%</u>
	<u>Nickel</u>	<u>88%</u>	<u>8%</u>	<u>4%</u>
	<u>Chromium</u>	<u>84%</u>	<u>12%</u>	<u>4%</u>
	<u>Vanadium</u>	<u>86%</u>	<u>9%</u>	<u>5%</u>
<b><u>High Volatility Metals</u></b>	<u>Arsenic</u>	<u>33%</u>	<u>63%</u>	<u>4%</u>
	<u>Lead</u>	<u>4%</u>	<u>96%</u>	<u>&lt;0.2%</u>
	<u>Cadmium</u>	<u>4%</u>	<u>96%</u>	<u>&lt;0.3%</u>
	<u>Mercury</u>	<u>0%</u>	<u>100%</u>	<u>0%</u>
	<u>Zinc</u>	<u>8%</u>	<u>92%</u>	<u>&lt;0.2%</u>
	<u>Tin</u>	<u>36%</u>	<u>64%</u>	<u>0%</u>

Source: Global Energy 2001a.

Table 3.1-2 shows the trace concentrations of metal in the process water and compares the concentrations to the limits established by the Toxicity Characteristic Leaching Procedure (TCLP) used by the U.S. Environmental Protection Agency (EPA). The process water is retained within the system and would not be directly discharged prior to treatment. During a typical treatment process, lime would be added to the water to condense any metals contained within. The concentrations of the different metals would be significantly reduced as the metals condense onto the lime. The lime would also be removed from the water prior to discharge. The only metal within the process water to exceed TCLP limits is selenium.

The last zone within the BGL gasification unit is located at the bottom of the unit and is the vitreous frit production zone. This zone is at the bottom of the partial oxidation zone, where the temperatures are high enough to melt any inorganic materials contained within the fuel feed column, including the RDF pellets and form a molten glassy material. This molten material collects in a pool below the hearth and is periodically removed via a taphole at the bottom of the pool. The material then drops into a water quench tank, where it cools at a high rate that causes it to shatter and form a black, glassy, sand-like material. Unlike the ash formed from incinerators, which is a hazardous waste due to its leachable nature, the vitreous frit from 100 percent coal-fed units has been shown to be nonleachable by EPA test protocols and can be marketed as a product. Should the frit from these gasifiers be nonleachable, it can be used without further processing in a number of areas, including road-building aggregate (Vick 2001).

Tables 3.1-3, 3.1-4, and 3.1-5 present the Ultimate and Mineral Analyses for a sample of frit from a commercial scale BGL gasifier operating on a 100 percent coal feed. Appendix E provides the results of an analysis for a full screen of the Universal Treatment Standards constituents. As the data shows, the test results are either nondetect or well below the criteria, which are more stringent than the TCLP criteria, indicating that the frit is benign. The trace elements presented in Table 3.1-5 are located within the silica matrix of the frit and, as shown in Appendix E, do not leach to any significant extent. Since this project would operate on a different feed than the project the frit sample came from, the first batch of frit generated by the project should undergo TCLP testing to ensure that the frit will be benign.

### **Sulfur Removal and Recovery**

The sulfur compounds are removed from the raw syngas in two steps, acid gas cleanup and sulfur recovery. The acid-gas cleanup is generally accomplished by using a selective amine-type solvent. The sulfur recovery units use a process unit that employs a specific chemical reaction, called the Claus reaction, to generate elemental sulfur. The elemental sulfur in these compounds will be a co-product and sold commercially. The quantity of elemental sulfur generated would depend directly on the sulfur content of the coal used. The selection of a coal source will not be determined until after project financing is completed. A bounding scenario based on 50 percent coal feed and 4 percent sulfur in coal, which is the worst-case for

sulfur production, equates to approximately 90.7 metric tons (89.3 long tons) per day of elemental sulfur. The 33,100 metric tons (32,600 long tons) per year would be a minor addition to

**Table 3.1-2. Typical Trace Metal Concentrations in Gasifier Facility Process Water**

<u>Metal</u>	<u>Concentration (ppm)</u>	<u>TCLP Limits (ppm)</u>
<u>Copper</u>	<u>&lt;1.100</u>	
<u>Vanadium</u>	<u>&lt;0.020</u>	
<u>Aluminum</u>	<u>3.190</u>	
<u>Cadmium</u>	<u>&lt;0.100</u>	<u>1.0</u>
<u>Arsenic</u>	<u>3.900</u>	<u>5.0</u>
<u>Mercury</u>	<u>0.028</u>	<u>0.2</u>
<u>Molybdenum</u>	<u>&lt;0.070</u>	
<u>Antimony</u>	<u>0.250</u>	
<u>Chromium</u>	<u>&lt;0.100</u>	
<u>Nickel</u>	<u>0.970</u>	
<u>Cobalt</u>	<u>0.023</u>	
<u>Zinc</u>	<u>&lt;0.400</u>	
<u>Selenium</u>	<u>2.060</u>	<u>1.0</u>
<u>Silver</u>	<u>&lt;0.040</u>	<u>5.0</u>
<u>Lead</u>	<u>0.200</u>	<u>5.0</u>
<u>Manganese</u>	<u>1.200</u>	
<u>Beryllium</u>	<u>&lt;0.010</u>	

Source: Global Energy 2001a.

Note: ppm is parts per million, TCLP is Toxicity Characteristic Leaching Procedure.

**Table 3.1-3. Ultimate Analysis for the Frit Sample**

<u>Parameter</u>	<u>As Received (Percent of Total)</u>	<u>Dry Basis (Percent of Total)</u>
<u>Moisture</u>	<u>0.11</u>	<u>N/A</u>
<u>Carbon</u>	<u>0.21</u>	<u>0.21</u>
<u>Hydrogen</u>	<u>0.01</u>	<u>0.01</u>
<u>Nitrogen</u>	<u>0.05</u>	<u>0.05</u>
<u>Sulfur</u>	<u>0.42</u>	<u>0.42</u>
<u>Ash</u>	<u>99.20</u>	<u>99.31</u>
<u>Oxygen</u>	<u>0.00</u>	<u>0.00</u>
<b>Total</b>	<b>100.00</b>	<b>100.00</b>

Source: Global Energy 2001b.

**Table 3.1-4. Mineral Analysis for the Frit Sample**

<u>Parameter</u>	<u>Weight (Percent of Total as Oxide)</u>	<u>Element</u>	<u>Weight (Percent of Total as Element)</u>
<u>Silica (SiO<sub>2</sub>)</u>	<u>34.71</u>	<u>Silicon</u>	<u>16.23</u>
<u>Alumina (Al<sub>2</sub>O<sub>3</sub>)</u>	<u>24.41</u>	<u>Aluminum</u>	<u>12.92</u>
<u>Titania (TiO<sub>2</sub>)</u>	<u>1.00</u>	<u>Titanium</u>	<u>0.60</u>
<u>Ferric Oxide (Fe<sub>2</sub>O<sub>3</sub>)</u>	<u>2.91</u>	<u>Iron</u>	<u>2.04</u>
<u>Calcium Oxide (CaO)</u>	<u>26.18</u>	<u>Calcium</u>	<u>18.71</u>
<u>Magnesia (MgO)</u>	<u>5.47</u>	<u>Magnesium</u>	<u>3.30</u>
<u>Potassium Oxide (K<sub>2</sub>O)</u>	<u>0.71</u>	<u>Potassium</u>	<u>0.59</u>
<u>Sodium Oxide (Na<sub>2</sub>O)</u>	<u>3.40</u>	<u>Sodium</u>	<u>2.52</u>

Source: Global Energy 2001b.

**Table 3.1-5. Trace Elements Found in the Frit Sample**

<u>Parameter</u>	<u>Concentration (microgram/gram)</u>
<u>Antimony (Sb)</u>	<u>&lt; 4</u>
<u>Arsenic (As)</u>	<u>&lt; 4</u>
<u>Beryllium (Be)</u>	<u>40</u>
<u>Boron (B)</u>	<u>1230</u>
<u>Cadmium (Cd)</u>	<u>&lt; 2</u>
<u>Chloride (Cl)</u>	<u>580</u>
<u>Chromium (Cr)</u>	<u>290</u>
<u>Cobalt (Co)</u>	<u>17</u>
<u>Copper (Cu)</u>	<u>50</u>
<u>Fluoride (F)</u>	<u>&lt; 20</u>
<u>Lead (Pb)</u>	<u>34</u>
<u>Manganese (Mn)</u>	<u>1140</u>
<u>Mercury (Hg)</u>	<u>0.03</u>
<u>Molybdenum (Mo)</u>	<u>&lt; 20</u>
<u>Nickel (Ni)</u>	<u>45</u>
<u>Silver (Ag)</u>	<u>&lt; 2</u>
<u>Thallium (Tl)</u>	<u>&lt; 4</u>
<u>Vanadium (V)</u>	<u>530</u>
<u>Zinc (Zn)</u>	<u>3</u>

Source: Global Energy 2001b.

annual domestic sulfur production, which was approximately 15.2 million metric tons (14.9 million long tons) in 1999. The majority of this, 13.1 million metric tons (12.9 million long tons), was produced by other energy companies in fuel refineries or natural gas exploration (ChemExpo 1999). The elemental sulfur produced by the Kentucky Pioneer IGCC Demonstration Project facility is similar to that produced by other energy companies, and is therefore readily marketable. The majority of the sulfur market, approximately 90 percent, is allocated to the development of sulfuric acid for fertilizer production (ChemExpo 1999). Liquid tankers are currently planned to transport the sulfur offsite; however, the choice of rail or truck transport will depend upon customer selection and their location.

The acid-gas clean-up process removes the sulfur compounds after the raw syngas has cooled. There are several technologies that can accomplish this process. Each process is based on the absorption of the sulfur into a selective amine-type solvent. The Kentucky Pioneer IGCC Demonstration Project facility would utilize an acid-gas clean-up process that is expected to achieve better than 99 percent sulfur removal, lowering the clean syngas sulfur to 40 parts per million or less H<sub>2</sub>S. The specific acid-gas clean-up process has not yet been determined for the Kentucky Pioneer IGCC Demonstration Project. For example, the acid-gas clean-up technology could include the Purisol technology developed by Lurgi and the Selexol™ process developed by UOP, LLC (EIV 2000).

The acid-gas clean-up process consists of washing, absorption, stripping, and regeneration to remove sulfur and other contaminants from the syngas. The sulfur removal process absorbs sulfur compounds in a selective solvent. The removal of contaminants occurs in the absorber tower. The syngas will enter the bottom of the absorber and pass through a prewash section where naphtha, hydrogen cyanide, and other undesirable compounds are removed by washing with a portion of the solvent stream. The prewash solvent is circulated to a stripper and extractor where the contaminants are removed and recycled to the gasifier. The prewash syngas then enters the main wash section of the absorber in order to remove the H<sub>2</sub>S. This section also contains COS hydrolysis trays to convert COS to H<sub>2</sub>S to allow its removal. The H<sub>2</sub>S-free syngas then enters the final, upper portion of the absorber and is washed by demineralized water to remove any solvent vapors remaining in the desulfurized syngas. The water-saturated syngas is then routed to the gas turbines through the preheat/saturation area.

The H<sub>2</sub>S absorbed by the solvent in the absorber or reabsorber is removed by indirect steam stripping in the hot regenerator. The stripped H<sub>2</sub>S is sent to the Claus Sulfur Plant and then the regenerated solvent is circulated back to the absorbers. The gas stream containing primarily H<sub>2</sub>S generated in the acid-gas clean-up process is sent to the Sulfur Recovery Unit where the sulfur compounds are converted to elemental sulfur using the Claus reaction. The gas stream first reacts with air in a combustion chamber to produce sulfur dioxide (SO<sub>2</sub>). Next, the gas is cooled and sent through the Claus reactors where a highly active aluminum oxide catalyst induces conversion to elemental sulfur. In addition, the gas undergoes a reaction known as the Claus reaction in which the SO<sub>2</sub> produced in the first step reacts with H<sub>2</sub>S to produce elemental sulfur and water.

The gas would then pass through a hydrogeneration unit to convert all reduced sulfur back to H<sub>2</sub>S to allow cleanup of the small fraction of remaining sulfur. The Kentucky Pioneer IGCC Demonstration Project would recycle the tail gas back to the gas clean-up plant so that there are no SO<sub>2</sub> emissions from the sulfur recovery process.

The gasifiers could be shut down or placed on standby quickly if there is a problem during the acid-gas clean-up process or the sulfur removal process. The removal of oxygen injection and solid fuel addition rapidly removes heat and allows isolation of the reactor and avoidance or minimization of any flare or vent release of raw syngas. The gasifiers are routed to an emergency flare in case of malfunction (EIV 2000). The primary stream constituent to the flare is syngas diluted with water and nitrogen (N<sub>2</sub>). As stated previously, purified syngas is predominantly CO and H<sub>2</sub>, with small amounts CO<sub>2</sub>, methane, ethane, and sulfur present. These constituents and modern flare design generally result in CO, CO<sub>2</sub> and water as flare combustion products. Sulfur dioxide would result from the combustion of the relatively minor sulfur content. Raw syngas, before purification, would contain these main constituents and some heavier hydrocarbon compounds. Regulatory requirements accept that flares are essential components of safe plant design and account for potential flare combustion considerations in permit and non-permit requirements.

### **Synthesis Gas Feed**

The raw syngas is routed through processing units that reduce the temperature; remove particulate matter, tars, oils, and other hydrocarbons that may have been carried into the hot syngas; and remove any contained hydrogen chloride, in addition to the sulfur removal and recovery process. The particulate matter, tars, oils, and other hydrocarbons are reinjected into the gasifier unit for further processing and conversion to syngas. Once these steps are completed, the cleaned syngas, comprised of 55 percent CO, 30 percent H<sub>2</sub>, 10 percent CO<sub>2</sub>, 5 percent methane and ethane, and trace amounts of H<sub>2</sub>S, is used to fuel the gas turbines in the combined cycle power plant. Nitrogen and steam are blended into the cleaned syngas to dilute it, which provides further cooling of the gas to control and reduce NO<sub>x</sub> emissions. The nitrogen and steam blend also provides a higher mass flow to the turbines, which results in more power generation.

In the event the gasifier would not be needed, it would be placed on standby or shutdown. The removal of O<sub>2</sub> injection and solid fuel addition rapidly removes heat and allows isolation of the reactor and avoidance or minimization of any flare or vent release of raw syngas (EIV 2000).

#### **3.1.2.3 Supporting Project Facilities**

The supporting project facilities would include administrative offices, railcar loading and unloading areas, on-site utilities, steam-generating units, air emissions control equipment, and wastewater treatment equipment. The existing water intake structure located in the Kentucky River would also be modified to accommodate the additional water requirements of the facility.

Though detailed design has not been initiated, KPE has indicated that all of these supporting facilities, with the exception of the administrative offices and railcar loading and unloading areas, would be incorporated into the 4.8-hectare (12-acre) main power island facility, and are included under both No Action

Alternative 2 and the Proposed Action. Administrative offices are housed in existing buildings owned by EKPC on the site and are leased by KPE. Rail loading and unloading areas required for the Proposed Action would be integrated into the balance of the plant for optimal layout of the site and utilization of the process area.

### **3.1.3 Project Risk**

The proposed Kentucky Pioneer IGCC Demonstration Project would be a demonstration of a new technology under the CCT Program. Congress directed DOE to pursue the goals of the program by means of partial funding, or cost sharing, of projects owned and controlled by non-federal government sponsors. This project was first selected in 1993, with Duke Energy as the participant in partnership with an east coast utility; however, for various reasons the siting for the project was changed to a site in Illinois. In 1999, Global Energy, Inc., approached Duke Energy and requested to take over the project. KPE, a subsidiary of Global Energy, Inc., entered into a power purchase agreement with EKPC to buy the power from the Kentucky Pioneer IGCC facility. Because the currently proposed site for the project would provide for demonstration of the BGL technology and the power purchase agreement between EKPC would allow KPE to meet their repayment agreement with DOE, the partnership was determined acceptable.

The proposed facility would be the first commercial-scale demonstration of a co-fed BGL gasifier in the United States. The gasifier units used would also be between 40 and 50 percent larger than other existing units, allowing for greater syngas and electrical output from the facility. Because it would be the first demonstration of this technology, there would be a fair amount of financial risk for KPE associated with the operation of the facility. Another major financial risk for KPE is in securing a market for the vitreous frit produced in the gasification process. In addition to the loss of income if a market for the frit is not secured, KPE would have to bear all financial costs from storing and/or landfilling the frit. Although frit produced by gasification of coal has been found not to leach, frit resulting from the co-feed of coal and RDF has not been produced and therefore no leaching data is available. If the frit from the Kentucky Pioneer IGCC Demonstration Project is found to leach, it would not be marketable and the costs to temporarily store and landfill the frit would escalate significantly. Consequently, the financial success of the project is also dependant on the frit being deemed nonhazardous.

## **3.2 Fuel Source**

The solid fuel source for the Kentucky Pioneer IGCC Demonstration Project would be high-sulfur coal and RDF pellets. RDF pellets would be procured from an RDF pellet manufacturer. The two fuel sources would be shipped by rail directly to on-site storage. At least 50 percent of the feed would consist of high-sulfur coal from the Kentucky region during the 1-year demonstration period (Global Energy 2000b).

### **3.2.1 Coal**

KPE intends to use high-sulfur coal as the coal fuel co-feed; it will be procured for direct delivery to the project site. Western Kentucky coal is generally considered the high-sulfur coal region; however, Eastern Kentucky may also provide high-sulfur coal supplies. Project economics would determine the supplier and the type of coal supplied (Global Energy 2000b). The facility would require approximately 2,268 metric tons (2,500 tons) per day of coal, which equates to about 25 railcars per day. Compared to conventional coal-fired electric generation technologies, this project would require less coal consumption to generate 540 MW.