Synfuel Park / Polygeneration Plant
Feasibility Study for Indiana

Prepared for the
Center for Coal Technology Research (CCTR)
State of Indiana

Paul V. Preckel, Principal Investigator
Zuwei Yu, Co-Principal Investigator

State Utility Forecasting Group
Energy Center at Discovery Park
Purdue University

John A. Rupp
Fritz H. Hieb

Indiana Geological Survey
Indiana University

With Contributions By: Devendra Canchi, Sika Gbègbèlègbè Dofonsou, Agnieszka Drobniak, Sisi Guo, and Akiner Tuzuner

September 30, 2007

Revised January 31, 2008

Table of Contents

APPENDICES
Appendices A through E are available on the CCTR website at:
http://www.purdue.edu/dp/energy/CCTR/researchReports.php

Appendices A through E are available on the CCTR website at:
http://www.purdue.edu/dp/energy/CCTR/researchReports.php

List of Tables

Appendix Tables

Appendices A through E are available on the CCTR website at:
http://www.purdue.edu/dp/energy/CCTR/researchReports.php

List of Figures

Appendix
Figures

Appendices A through E are available on the CCTR website at:
http://www.purdue.edu/dp/energy/CCTR/researchReports.php

Acknowledgments

The authors are grateful for funding, technical, and other support of this project by the Indiana Center for Coal Technology Research (CCTR). We also thank Suzanne Black, Aimee Kappes, Wendy Madore, Eric Smoldt, and Barbara Gotham for proofreading, graphics, and editing services.

The authors also thank the following people for providing advice, arranging site visits, and providing information and data:

Mr. Rich Cooper, Executive Director, Ports of Indiana
Mr. Kent Curry, Director of Regulatory Affairs, American Electric Power
Mr. Daren Eliason, Process Engineer, Dakota Gasification Company
Mr. Randy Haymaker, Director of Public Affairs, Hoosier Energy
Mr. Kent Holcomb, General Manager, Francisco Mine, Indiana
Mr. Renus Kelfkens, Sasol North America
Dr. Thomas Lynch, Chief Engineer, Wabash IGCC Gasification Plant
Dr. Maria Mastalerz, Senior Scientist, Indiana Geological Survey
Mr. Kriss Miller, FGD Manager, Merom Generating Station, Hoosier Energy
Mr. Mark Newlin, General Manager of Regulatory Affair, Duke Energy Indiana
Mr. Mike Rampley, Vice President of Marketing and Business Development, Hoosier Energy
Dr. Mike Reed, System Analyst, NETL/DOE
Mr. Mark Sabree, Business Manager, the Black Beauty Mine, Peabody, Indiana
Mr. Phil Wilzbacher, Port Director, Port of Indiana Mount Vernon

Indiana Geological Survey (IGS) is a subcontractor for the project, and is responsible for research and support in coal supply and the assessment of the potentials for CO_2 sequestration and enhanced oil recovery (EOR), the enhanced coal bed methane (ECBM), and the enhanced shale gas production analyses.

For questions and comments, please contact:

Paul Preckel: preckel@purdue.edu
John Rupp: rupp@indiana.edu
Zuwei Yu: zyu@purdue.edu

Executive Summary

With increasing concern about the finite nature of worldwide petroleum reserves, as well as the lack of political stability in regions where those reserves are located, interest is rising in the conversion of coal and biomass into clean fuels, particularly liquid transportation fuels, as well as chemicals and synthetic natural gas (SNG). A number of states with substantial coal reserves within their borders are mounting efforts to site coal to liquids (CTL), coal to gas (CTG) and coal-based chemical plants. Indiana is no exception, and the accompanying report has been produced at the behest of Indiana's Center for Coal Technology Research (CCTR). The goal of this report is to do a preliminary assessment of the suitability of several sites in southwest Indiana for the location of one or more coal conversion facilities.

The team has evaluated in detail eight sites in southwest Indiana, including 1) one in the Breed/Fairbanks area, 2) one in the Francisco area, 3) one by the Minnehaha mine, 4) one by the Merom Power Station, 5) one in the NSA (Naval Supporting Activities) at Crane in Martin County, 6) the one in the NSA by Lake Glendale in Sullivan County, 7) one by the Port of Indiana at Mt. Vernon ,and 8) one by the CountryMark Refinery in Mt. Vernon. Although Figure I shows only five of the eight sites, the circles cover all eight.

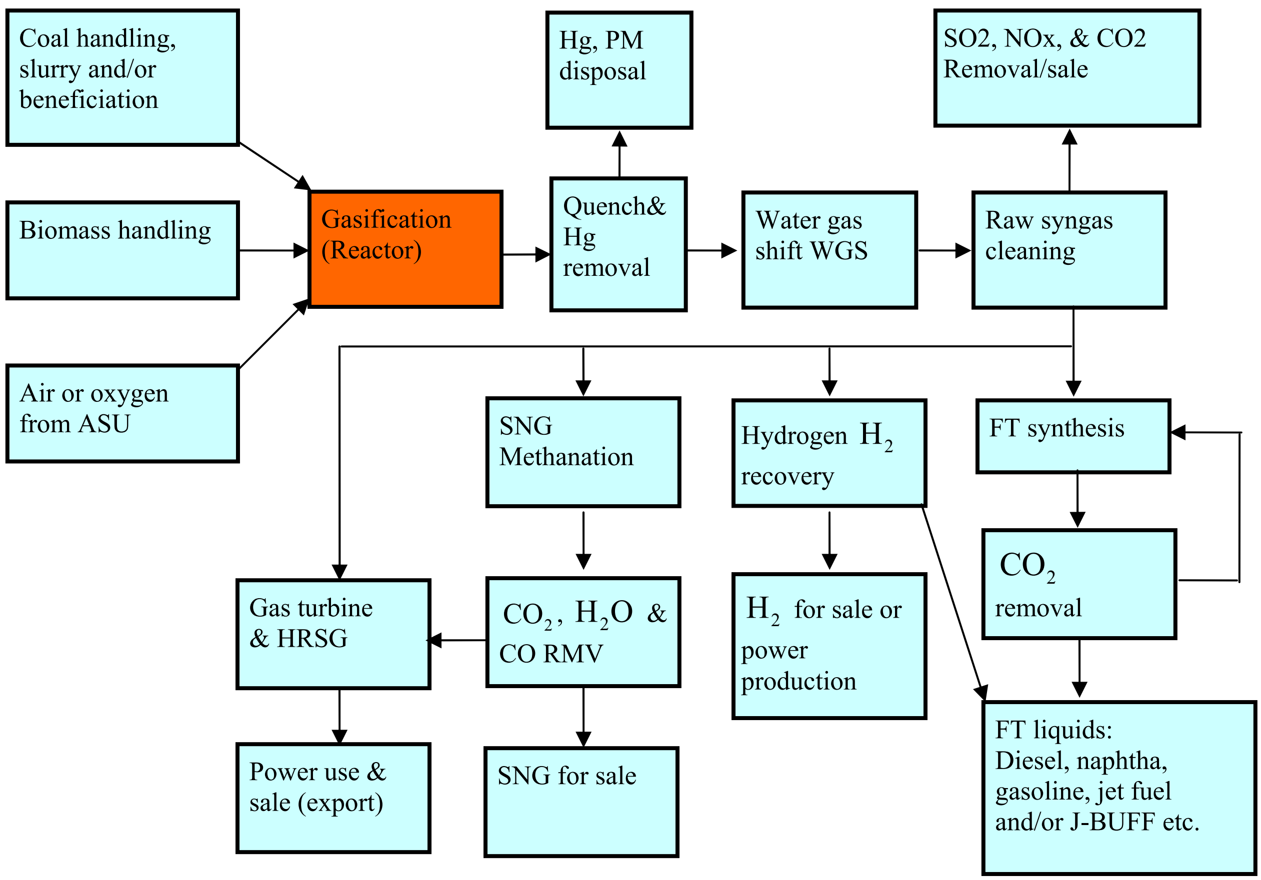
Seven additional sites have been selected as potential sites for further study, including (1) one near the Gibson Power Station, (2) one near the A.B. Brown Power Station, (3) one near the F.B. Culley Power Station, (4) one near the Rockport Power Station, (5) one near Tell City, (6) one inside the Indiana Arsenal between Jeffersonville and Charlestown, and (7) one near the Wabash IGCC power plant west of Terre Haute, Indiana.

These preliminary assessments focus on the availability of the resources and infrastructure that would permit the development and operation of a coal conversion facility. The major resources include land and water. There is also an evaluation of proximity of coal resources and the potential for CO_2 sequestration or other use (e.g., for enhanced oil recovery or enhanced coal bed methane or shale gas production). The infrastructure needs also include assessing the access to the electric power grid, natural gas and petroleum product pipelines, major roads, and rail systems.

The major conclusions are: (1) all of the sites examined are feasible for the development of a synfuel park, (2) due to limited water resources, some sites may not be appropriate for large capacity plants or for production of SNG or pure hydrogen, (3) special considerations must be given to the transportation of large pieces of equipment such as gasifiers and reactors to the plant site, which makes the sites located along major rivers that could accommodate barge deliveries advantageous, (4) generally there is some sequestration potential associated with each site although some sites clearly have significantly higher potential for the enhanced production of petroleum using produced CO_2, and (5) although the proximity of major infrastructural components, including transportation systems for products and feedstock, occur near each of the sites, the ability of these systems to handle the increased loads associated with such a synfuels park will need to be further evaluated.

I. Introduction

This report summarizes the findings of a project focused on a preliminary assessment of the potential of several sites in Indiana to serve as the location of one or more Synfuel Park/Polygeneration Plants. This assessment has been performed for the State of Indiana, funded by the Center for Coal Technology Research (CCTR). The primary contractor is the State Utility Forecasting Group (SUFG) in the Energy Center of Discovery Park at Purdue University, with a subcontract to the Indiana Geological Survey (IGS) at Indiana University. The contract period spanned from July 2006 to September 2007.



Legend: J-BUFF = Joint Battlespace-Use Fuel of Future of DOD (Sasol Outlines, 2007), HRSG = Heat recovery steam generator, RMV=removal.

Figure I.1. Flow diagram of the Synfuel Park/Polygeneration Plant

Synfuel is short for synthetic fuel, which can be produced from a variety of feed stocks, including coal, biomass, algae, etc. The synfuel product can take various forms such as liquid, solid and gas. In this report, coal is the primary feed stock for synfuel production, with biomass serving as a secondary feed stock. We focus on liquid and gaseous synfuels, including liquids derived from the Fischer-Tropsch (FT) process (Department of Trade, 1999), synthetic natural gas (SNG), and, for some sites, the possibility of hydrogen. Co-production of electric power is included via an integrated gasification combined cycle (IGCC) generating unit. Direct coal liquefaction (DCL) is not considered in this report due to the higher capital cost of DCL. A flow chart diagram of the synfuel park/polygeneration plant (hereafter referred to as a synfuel park) is illustrated in Figure I.1 and Appendix A, in which FT diesel, jet fuel, gasoline, wax/lubricants, hydrogen and power are the likely finished products. Other products, such as methanol and DME (dimethyl ether) can also be produced (SES and Golden, 2007). However, we concentrate on the analysis of FT diesel, jet fuel, SNG, hydrogen and power in this study.

This report assesses the feasibility of locating a synfuel park at each of six sites according to the following criteria:

- Coal availability
- CO_2 sequestration potential
- Transportation infrastructure/logistics
- Land/real estate requirements
- Transmission lines and power availability
- Gas and oil pipelines
- Water requirements and resources
- Waste disposal and environmental issues
- Risk factors
- Labor force/availability

Eight sites have been evaluated in detail as potential locations for synfuel parks in this report:

(1) One near the Francisco Mine in Gibson County;
(2) One near the Fairbanks/Breed in Sullivan County;
(3) One near the Minnehaha Mine in Sullivan County;
(4) One near the Merom Power Station in Sullivan County;
(5) One near the Port of Indiana at Mt. Vernon;
(6) One near the CountryMark Refinery in Mt. Vernon;
(7) One at the Naval Supporting Activities at Crane (NSA Crane) in Martin County; and
(8) One the NSA Crane Sullivan Site.

In addition, seven backup sites are also preliminarily evaluated and compared, including

(1) One by the Gibson Power Station in Gibson County;
(2) One by the A.B. Brown Power Station in Posey County;
(3) One by the F.B. Culley Power Station in Warrick County;
(4) One by the Rockport Power Station in Spencer County;
(5) One near Tell City in Perry County;
(6) One in the Indiana Arsenal, Jefferson; and
(7) One near the Wabash Valley Power Association's IGCC power plant west of Terre Haute.

Coal gasification is one of the critical sections of the synfuel park. Gasification can be carried out *aboveground* or *underground*. In an aboveground gasification system, high temperature, high pressure reactors are used to create precisely controlled chemical reactions with primary inputs of coal to produce raw syngas, plus steam and/or oxygen. The resulting heat content of the syngas is very stable. Coal gasification can also be performed *underground*, in which case an underground tunnel in a coal bed is used as a "gasifier" without the use of an actual steel reactor vessel. The advantage of this scheme is lower cost because the coal does not need to be mined or transported, a costly steel gasifier containment vessel does not need to be used, and the slag/ash does not need to be handled and transported for disposal purposes. The disadvantage of underground coal gasification (UCG) is that the syngas stream may have less consistent heat content. A number of UCG projects have been proposed around the world, including the Chinchilla UCG IGCC in Australia (Chincilla Pilot, 2007), the ESKOM 2,100 MW UCG/IGCC electricity generation plant in South Africa (Olivier, 2007), and the UCG synfuel project in China (Global Energy Network, 2007). In this report, however, we consider *aboveground gasification* exclusively because site evaluation is far more complicated due to the need to actually evaluate the underground coal bed, water issues and other aspects of geology.

The FT process was developed by two German scientists, Franz Fischer and Hans Tropsch, in 1923. The process is an indirect coal liquefaction (ICL) process. ICL, including the FT process, is a mature technology. In the past commercialization of ICL technology was not widespread, for the simple reason that oil prices did not remain high enough for a long enough period of time. However, due to the high crude oil prices of the past few years and concerns about national energy security, many countries have been considering the development of ICL plants for producing synfuels. The current leader in plant construction and development is China, with a few large commercial projects under development, and many more in the planning stage.

ICL and the FT process have been developed and used successfully for some time. At the end of World War II, Germany was operating nine indirect and 18 direct coal liquefaction plants. Direct coal liquefaction, or DCL, plants involve a somewhat different technology from ICL, but have the same ultimate goal of creating liquid fuels from coal. These plants supplied Germany with almost four million tons of fuel (both diesel and gasoline) per year (Department of Trade, 1999).

Since the early 1950s, South Africa has been the world leader in production of ICL liquids, with three large commercial plants. The Sasol Company has been the major force in ICL research, development, and operation. They have achieved substantial improvements over the original FT synthesis process, including the use of iron-based catalysts, the high temperature FT (HTFT) fluidized circulating bed technology, and the Sasol Advanced Synthol (SAS) technology. The fuels which have been the primary products serve up to 60% of South Africa's oil demand. The plants also yield a substantial amount of various chemical feedstocks (see Department of Trade, 1999, and Figure I.2). Additional details of the FT process may be found in Appendix D of this report.

The U.S. has conducted significant research in the ICL area with sponsorship from both industry and government. ExxonMobil, Rentech and Syntroleum have independently developed ICL processes. One commercial plant using ICL technology, the Eastman Kingsport methanol plant, has been operating successfully for the past 10 years, with co-sponsorship from the U.S. Department of Energy (DOE).

We now provide brief and general descriptions of the site selection criteria. More detailed descriptions of these criteria are provided in sections II-IX and XVIII.

- Coal resources – In general, coal is plentiful in Southwestern Indiana in particular and in the Illinois Basin in general (see Figure II.1). However, each site may be closer or farther away from coal sources, which may affect plant economics and railroad congestion.

- CO_2 sequestration and other uses – CO_2 capture and sequestration is not currently required in the U.S. However, it may become economically advantageous due to the potential imposition of carbon taxes or a cap-and-trade policy in the future. It appears that Southwestern Indiana has good potential for sequestration, including deep aquifers. In addition, other uses including enhanced oil recovery (EOR) from nearly exhausted oil wells/fields, enhanced coal bed methane (CBM) production, and enhanced shale gas/oil production may prove to be economical uses of CO_2. Each potential synfuel park site may be closer to or farther away from these resources, which will affect plant economics and construction lead times.

Figure I.2. The Sasol Secunda Synfuel Plant, South Africa (Department of Trade, 1999)

- Transportation infrastructure/logistics – Southwestern Indiana has a good rail system and is also accessible to the Ohio and Wabash Rivers. However, each site has its own unique transportation features. For example, low overpasses may impede the transportation of very large equipment, which in turn may affect costs of plant construction. In addition, the impacts of congestion may be site specific and may affect costs of coal supply and finished products distribution.

- Electricity transmission lines and gas/petroleum pipelines – These resources are needed for different purposes during the construction and operation phases. Electricity and gas may need to be imported to the site during the construction phase. However, most designs investigated involve some export of electricity during the operation phase. In addition, either gas or petroleum pipelines may be needed during the operation phase for export of products.

- Water resources – Water requirements are substantial, with the majority of estimates ranging from 7-15 barrels of water per barrel of FT liquids. The use of air cooling or hybrid systems can substantially reduce the water needs. There is also the potential for realizing economies of scale in water use for larger operations through increased recycling of water.

- Land resources – a small synfuel park (i.e., 10,000 barrels per day) with FT production capacity is estimated to require about 120 acres for the plant, including water cooling and treatment, and co-production of electric power. An additional 20 acres is required for coal handling, and substantial land 500-1,000 acres (depending on topography) is needed for slag and ash disposal.

- Waste disposal and environmental considerations – Synfuel plants with CO_2 sequestration are relatively benign from an environmental perspective. Waste water can be treated to remove pollutants. Based on IGCC experience, air emissions are superior to pulverized coal power plants. Solid wastes, primarily in the form of slag and ash, are inert and may be useful as construction materials.

- Labor resources – The National Energy Technology Laboratory (NETL) estimates 144 direct operations personnel for a 50,000 barrel per day (bpd) plant. Administrative, maintenance and other support personnel are likely to add another 40-50 percent. The scaling of the labor needs is probably not linear, with smaller scale operations requiring more labor per barrel of capacity.

- Economic impact – NETL estimates that revenues (including power export) are on the order of about $80 per barrel of FT liquids. Even for a small plant (i.e., 10,000 barrels per day) running at a 90 percent capacity factor, this amounts to revenues of three quarters of a million dollars per day. The indirect impact would be much larger through the economic multiplier effect, which is particularly high for the coal mining sector. More information regarding the economic impact of synfuel park/polygeneration plants can be found in Irwin et al. (2007).

Our major conclusions are as follows:

(1) Coal, natural gas, water, and geological sequestration resources are available, to varying degrees, at each of the eight sites to operate synfuel parks with co-production of electric power. The capacity varies with the sites, from a very large plant with a potential capacity of 50,000-100,000 bpd at Mount Vernon, to about 10,000-20,000 bpd in the Minnehaha area or the NSA Crane site in Sullivan County.

(2) Power and gas transmission lines are available either onsite or nearby and should be able to handle the added load required during construction. However, if significant amounts of power and/or SNG are to be exported, these infrastructures may have to be further evaluated for enhancement.

(3) The Mount Vernon site can take delivery of large equipment such as the FT reactors. A port on the Ohio River at Mount Vernon has a crane that can lift up to 1,000 tons per load, which would allow the use of very large FT reactors. The apparent economies of scale in ICL production as a function of reactor size give the Mount Vernon site an advantage in terms of production efficiency. Other sites would be restricted to smaller FT reactors due to transportation limitations imposed by the overpasses and tunnels on the rail or highway systems.

(4) Water may be a limiting factor for some sites such as the Minnehaha mine-mouth site. This gives an advantage to sites with access to large, flowing bodies of water such as the Ohio and Wabash Rivers.

The remainder of the report is arranged as follows: Section II analyzes coal resources, while Section III focuses on carbon dioxide sequestration. Section IV examines the infrastructure requirements; Section V describes water requirements. Section VI analyzes land resources. Section VII discusses the environmental issues associated with the synfuel park. Emissions and waste disposal issues are analyzed in detail. Sections VIII and IX address labor requirements and economic impacts. Sections X through XVI cover the analysis of the seven primary sites, including their advantages and disadvantages. Section XVII presents preliminary analysis of a few more sites that could be good synfuel park candidates. Section XVIII discusses some policy and regulatory issues related to synfuel park development in

Indiana. Section XIX presents a report summary and suggests directions for future work. Various background documents are provided in Appendices A-D, and the results of the evaluation of sequestration, enhanced oil recovery, enhanced coal bed methane, and enhanced shale gas production potential are presented in Appendix E.

II. Coal Resources

Coal is available in abundance in southwestern Indiana. Figure II.1 shows the region where coal is available in Indiana, amounting to some 20 counties in the mining area. As shown in the apex of the resource triangle in this figure, the available resources for surface and underground mining amount to over 17 billion tons of coal. This amount is sufficient to supply a substantial clean coal conversion industry for at least the next 500 years. Thus, the availability of coal is not a limiting factor in considering the establishment of a synfuel park in southwest Indiana.

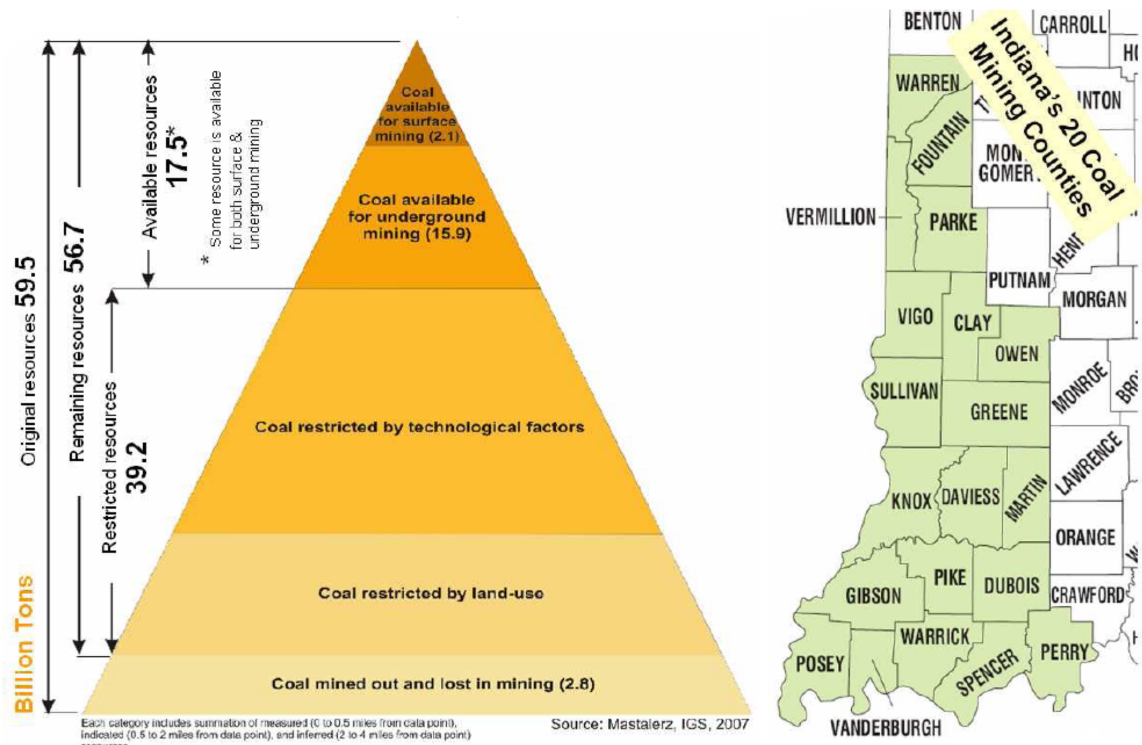


Figure II.1. Coal availability in southwest Indiana

III. CO_2 – Sequestration and Other Uses

The deep subsurface geology of the state has significant potential for use in the sequestration of produced carbon dioxide. There are four basic geological options or types of reservoirs available including injection into: (1) saline aquifers, (2) mature oil and gas fields (including the potential for use in enhanced oil recovery (EOR) projects using CO_2 flooding), (3) deep unminable coal seams (including the potential use for enhanced coal bed methane (ECBM) production), and (4) organic rich gas shales which also have the potential to produce enhanced shale gas.

These four sequestration options were evaluated for five of the principal sites in the southwestern part of the state. The area surrounding each site was defined as a circle with a twenty five mile radius. The index map in Figure III.1 shows the location of each of the five sites evaluated for sequestration potential with the respective circular areas.

The parameters used in these evaluations and the means by which these parameters were used to make the quantitative assessments are the same as those used in the national sequestration capacity assessments (NETL, 2007). The results of these evaluations are presented in maps and tables in Appendix E.

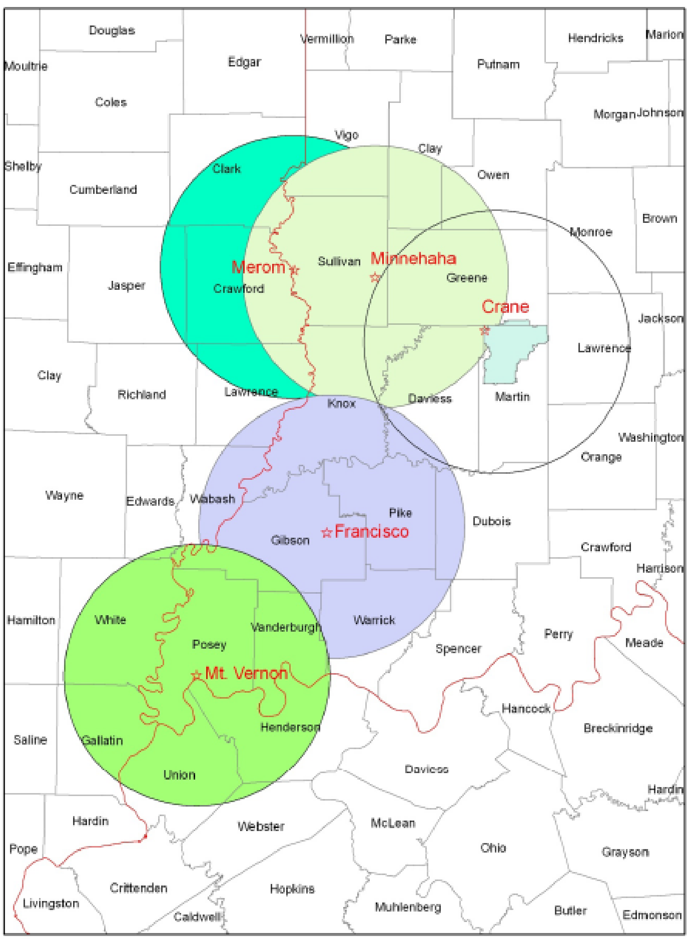


Figure III.1. Twenty-five mile radius buffer regions surrounding five locations covering the eight primary sites for potential synfuel parks. The analysis of Crane in Martin County was completed earlier and the results included in CCTR evaluation of that site (Irwin et al. 2007).

IV. Infrastructure – Transportation/LLogistics, Electricity Transmission, and Gas/Petroleum Pipelines

Infrastructure is needed to support the synfuel park in two distinct phases: the construction phase and the operation phase. The network of supporting infrastructure in southwest Indiana is displayed in Figure IV.1.

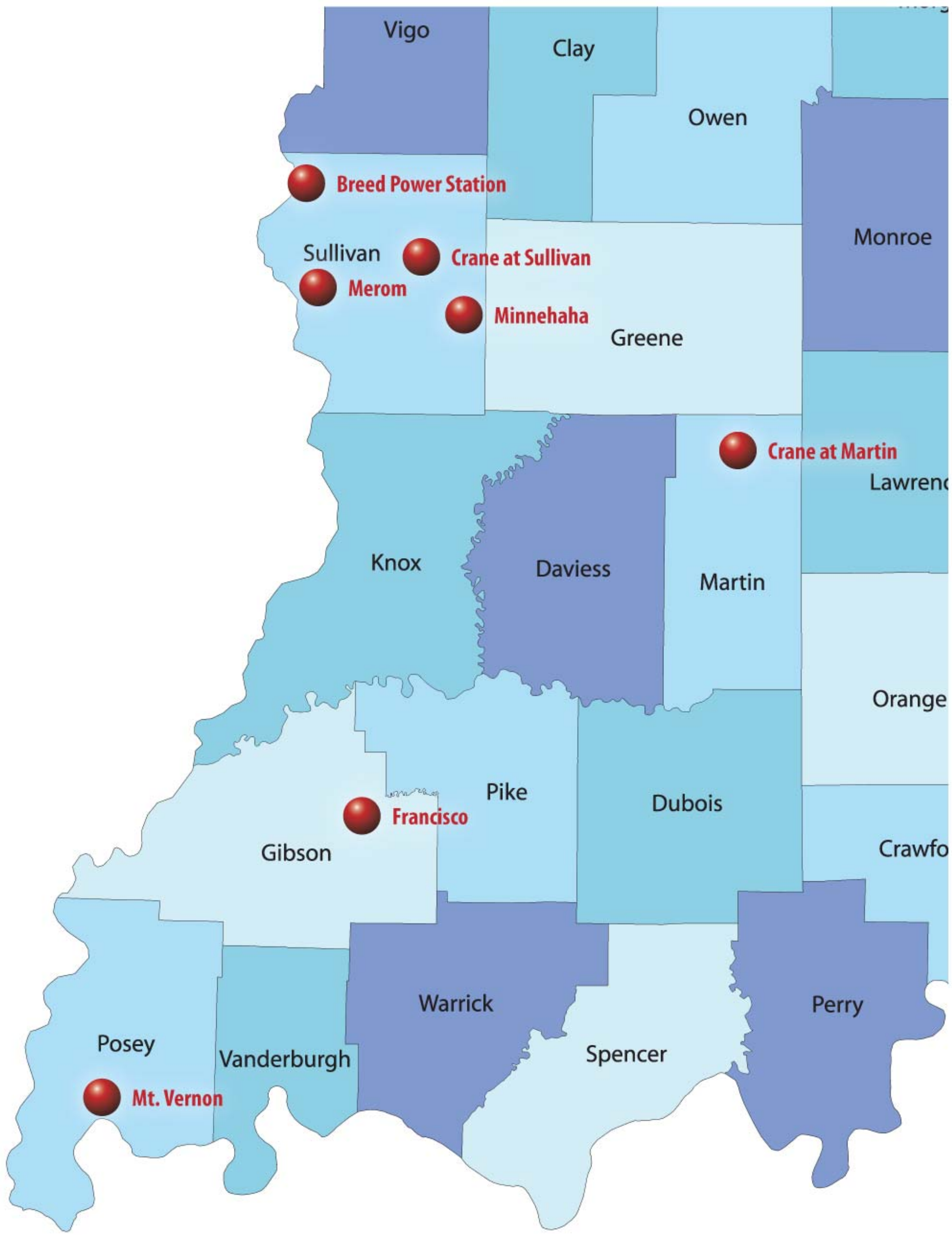


Figure IV.1. Potential site locations in southwest Indiana

IV.1 Transportation/logistics

Three processes require use of the transportation infrastructure: (1) shipment of large components of the synfuel park (mainly gasifier(s), raw syngas cleaning units, FT reactors, and liquids upgrading equipment) during construction, (2) the transportation of coal to the park, and (3) the distribution of finished products. These issues are discussed separately below.

IV.1.1 Shipment of large pieces of equipment

Gasifiers, hydro-crackers, ASUs and especially FT reactors are quite heavy and large. A gasifier may weigh 200 to 300 tons, with a diameter ranging 5-7 meters. The exception is the Rocketdyne type gasifier which is only about one tenth the size of competing gasifiers (Rardin, Yu, Holland, Black, Oberbeck, 2005). A Sasol FT synthesis reactor with a capacity of 20,000 bpd can weigh over 2,000 tons and have a diameter of about 33 feet (10 meters) and a height of over 180 feet (Foster Wheeler, 2005) (see Figures IV.2 and IV.3). Fortunately, gasifiers and FT reactors can be manufactured in various sizes according to customer requirements. According to Sasol (Ganter, 2005), a Sasol low temperature FT reactor with a capacity of 17,000 bpd may weigh approximately 2,200 tons, and for shipping purposes, its diameter is 10 meters with a length of 60 meters. Therefore, a FT reactor with a capacity of about 2,500 bpd could weigh less than 400 tons (2,200/7 ≈ 314 tons), and its diameter could be less than 6 meters and its height less than 20 meters depending on pressure and other parameters (1 meter = 3.28 feet).

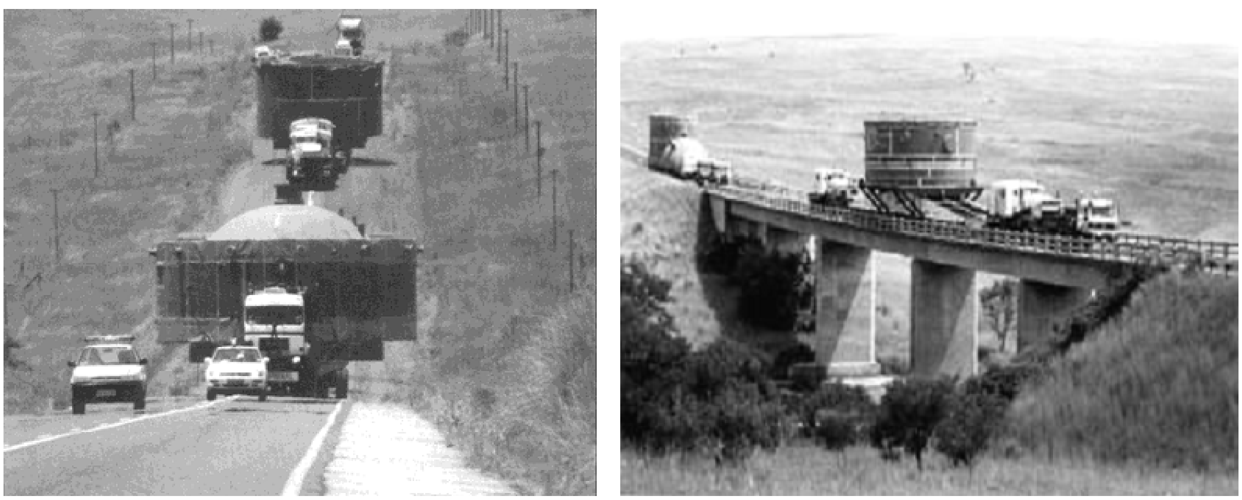


Figure IV.2. Transportation of very large FT reactors (Appendix B)

As reported in Appendix B, it is almost impossible to transport very large equipment on the interstate highway system due to restrictions on weight as well as the frequency of narrow passageways and low overpasses. Hence, we only consider using the rail system to transport very large facilities.

The shipping strategy may depend upon the place the equipment is manufactured. From a shipping perspective, the most challenging pieces of equipment are likely to be the FT reactors. Sasol does not have the capability to manufacture its own FT reactors and has been contracting with Japanese and Korean companies for the manufacture of reactors. If Sasol FT reactors are chosen, they are likely to be manufactured in either Japan or Korea, and shipped by sea with ultimate delivery via the Mississippi River to the Ohio River to southern Indiana. If U.S. technology is used for an FT portion of the plant, the equipment could possibly be manufactured in the U.S. and transported via the rail system. In this case, overpasses may also hinder the use of very large FT reactors at the Francisco site. Onsite manufacturing of large FT reactors is conceptually feasible, but may not be economical since special tooling and staff are involved. Even in the case of domestic sourcing of the FT reactor(s), shipping primarily via waterways is likely to be preferred.

Figure IV.3. Onsite transportation of the Sasol FT Reactor for the Sasol Qatar Oryx GTL Plant (Louw, 2006. The capacity is 34,000 bpd, with 2 FT reactors; each weighs 2100 tons)

There are two primary sites on waterways adjacent to southwest Indiana with the capacity to handle large equipment. Both the Jeffboat facility in the Jeffersonville/New Albany area and Mount Vernon can unload units weighing over 1,000 tons. Jeffboat is the largest single-site inland shipbuilding and repair facility in the U.S. In addition to building tanker and hopper barges, Jeffboat also operates a dock.

Once large equipment is unloaded at either Jeffboat or Mount Vernon, the best strategy for its delivery will be via rail. For the largest pieces of equipment, specialized train cars will likely be needed. According to Appendix B, up to 850 tons can be loaded onto a specialized type of railroad freight car called a Schnabel car. Schnabel cars are designed to carry heavy and oversized loads in such a way that the load itself makes up part of the car. The largest Schnabel car in operation, owned by ABB, carries the number CEBX 800, and is used in North America. It can carry loads up to 113 ft 4 in (34.5 m) long. For comparison, a conventional boxcar currently operating on North American railroads measures 50 to 89 ft (15.2 to 27.1 m) long and has a capacity of 70 to 105 tons. (See Table IV.1) The impediments to rail transport from either Jeffboat or Mount Vernon will be assessed on a site by site basis.

Table IV.1. Specification of Schnabel Car CEBX 800 (CEBX 800, 2006, and Appendix B)

Capacity	1,779,260 lbs.
Light Weight	740,890 lbs.
Load Limit	1,779,260 lbs.
Number of axles (33" wheels)	36
Empty Car Length	231' 8"
Maximum Loaded Length	345' 0"
Maximum Vertical Load Shifting Ability	44"
Maximum Horizontal Load Shifting Ability (either side of car center line)	40"

IV.1.2 Shipment of coal

A synfuel park producing 10,000 bpd of FT liquids with about 50 MW of power export consumes on the order of 5,000 tons of coal per day. With train coal car capacity of about 100 tons, this means that about 50 train car loads of coal are needed per day to feed a plant in full operation. Thus, one train of 100 cars delivering coal to the plant every other day is required to maintain the park at full operation. Capacity of the rail system will be assessed on a site by site basis.

IV.1.3 Shipment of finished products

Primary finished products of a synfuel park are likely to be FT diesel, gasoline, military fuel(s), naphtha, SNG and/or hydrogen. Sulfur is a byproduct that can be sold or given away for use in fertilizer production. Because of its volume, slag/ash are likely to be interred in a landfill in a nearby area; however, this material may have value as a construction material, in which case consideration should be given to export of this material from the plant site. These products can be shipped via rail. State highways can also be used for lower volume products.

IV.2 Electricity transmission lines

Electricity will probably be needed onsite during the construction phase of any synfuel park. The exact needs will be specified by the park's contractor, but it is unlikely that the capacity needs for electricity input during the construction phase will be any greater than the capacity needs for electricity output during the operation phase as we address next.

Synfuel parks have substantial internal needs for electricity. To accommodate this need, most designs for synfuel parks include a power generation block, and it is typical for the generating capacity to exceed the needs of the park. As a result, the park needs power export capacity – that is, access to sufficiently high voltage lines in the electricity transmission network. Availability of these lines is assessed on a site by site basis. However, we note that an assessment of the stability of the network in the presence of the new generating unit is beyond the scope of the present analysis.

IV.3 Gas/petroleum pipelines

As with electricity, natural gas will probably be needed onsite during the construction phase of a synfuel park, and again the exact capacity needs will be specified by the contractor. In addition, if SNG is to be one of the products in the output mix for the synfuel park, then the required capacity will be driven by the rated output of SNG for the plant.

We do not anticipate any substantial need for petroleum products to be delivered by pipeline to the construction site. However, one means for out shipment of finished liquid products (i.e., diesel, naphtha, etc.) is via pipeline. This could be achieved by piggybacking product-specific pipelines on existing natural gas or petroleum pipelines.

V. Water Resources

Water requirements for a FT plant with electricity co-production depend on many factors, including capacity, design of the cooling tower, power output, and coal type. A synfuel park requires a substantial amount of water, with water demanded by almost every section of the plant, including the air separation unit (ASU), coal slurry or beneficiation system, syngas quench, water-gas shift (WGS), cooling towers, FT synthesis and upgrading, SNG, etc. The SNG section requires an additional WGS reaction for optimal conversion. The largest demand of water, however, is for cooling the gas turbines, assuming a wet cooling system is used. All-wet cooling is preferable if adequate water is available at reasonable cost. Water demand can be reduced by dry cooling, hybrid cooling and recycling of blow down water after treatment. However, in our analysis, we assume the use of all-wet cooling systems.

For a FT plant without SNG and hydrogen power sections, producing one barrel of FT fuel requires about 10-15 barrels of raw water. This estimate assumes power co-production is included, uses evaporation cooling towers, and depends on the design and choice of the facilities and the type of coal (see Irwin et al., 2007, and Van Bibber et al, 2007). For example, consider the DOE 50,000 bpd FT baseline virtual plant (Van Bibber et al.). The estimated water consumption for the 50,000 bpd FT plant is about 21,400,000 gallons per day (see Table 4-2 in Van Bibber et al.). Equivalently, water consumption is 509,524 bpd by the plant, which yields about 10.2 barrels of water consumed per barrel of FT liquids. This water consumption estimate is lower than some others, which may be a result of: (i) low power export (only 125 MW, i.e., 25 MW export per 10,000 bpd), (ii) a suboptimal hydrogen/CO ratio (2:1) for the FT synthesis.

According to the Department of Energy (2005), the planned Gilberton FT and power plant will consume about 28.4 barrels of raw water per barrel of FT liquids (this figure includes the water required to produce the planned 80MW gross power with 41 MW net power export). While this number is significantly higher than our estimate of 10-15 barrels per barrel of FT fuels, the Gilberton plant uses coal culm as the feedstock, which requires much more water than regular bituminous coal. In addition, the planned power export of the Gilberton plant is higher than usual at 82 MW per 10,000 bpd of capacity rather than the 50 MW we have assumed for a 10,000 bpd plant. Generally, a FT plant with a small power co-production needs about 14.5 barrels of raw water per barrel of FT liquid fuels produced (Boardman, 2007). According to a Rentech study, less water use is possible through water conservation and more efficient design (Rentech Projects, n.d.). In fact, dry cooling systems could be used, which would reduce raw water use significantly.

Water requirements for SNG production should be more than for FT liquids production because another WGS is required to make the CO/hydrogen ratio 3:1 for optimal methanation. (Methane, CH_4, is the primary component of SNG.) It is unlikely that large quantities of hydrogen gas can be purchased from other sources near a synfuel park anywhere in Indiana. Hence, WGS appears to be the only practical source of additional hydrogen if SNG is also a part of the synfuel park output mix. In terms per MWh basis, SNG may require 30-40% more water than the FT counterpart. The Great Plains Synfuel Plant has a contract for water supply of about 17,000 acre-feet from Lake Sakakawea, which is 10 miles from the plant site. The plant uses a 14 cell wet cooling tower (as shown in Figure V.1), with lignite coal input of about 18,750 tons per day from a nearby mine. Taking all of these factors into account, a synfuel park with a wet cooling system should use on the order of 5-15 barrels of water per ton of coal input, depending on the plant's efficiency and the mix of finished products.

Figure V.1. Cooling tower of the Great Plains Synfuel Plant (Department of Energy, Office of Fossil Energy, 2006)

VI. Land Resources

A synfuel park is a large facility requiring substantial land, not only for the various components of the plant, but also for coal storage and handling, water cooling and treatment, and disposal of solid wastes (mostly slag and ash). Precise land requirements depend on the scale of operation and on the details of the plant design, such as the facilities chosen; the product mix, including the amount of power co-production; the cooling system design; etc. These requirements can be placed into four categories: (a) the main FT plant, (b) coal storage, (c) slag/ash disposal and perhaps (d) a cooling pond.

VI.1 Main plant

Land requirements for the main plant are driven primarily by the volume of coal to be processed on an annual basis, but also on the type of equipment used and the intended output mix. For example, the use of very large FT reactors reduces the land requirement relative to the use of several smaller reactors. However, due to limits on the infrastructure for delivering large equipment, some sites may be unable to use very large facilities.

We develop our estimates of the land requirements for the main plant based in part on the layout for the planned Gilberton, Pennsylvania, FT plant. Because of the surrounding infrastructure and the intended plant capacity, this plant is a helpful template for estimating the synfuel park land requirements for a site that cannot accommodate large equipment. The layout was developed by a consortium called WMPI, with financial backing and management support from DOE. The plant is designed to use coal culm (low energy waste coal that nationally has about 60% of the Btu content of normal levels) as the feedstock, and the product mix is about 3,700 barrels per day (bpd) of FT diesel, 1,300 bpd of naphtha, and co-produced power with a net export capacity of 41 MW (Department of Energy, 2005). The plant's gross power capacity will be greater than 80 MW. The FT plant will be near a strip mine and an old power plant, as indicated in Figure VI.1. The FT and co-produced power will be located in the main plant, with a detailed footprint shown in Figure VI.2. The main plant will use Shell gasifiers, two Sasol slurry FT reactors, the Chevron iso-hydrocracking technology, a gas turbine generator and a steam power generator, plus other supporting facilities. All in all, the main plant will occupy about 75 acres of land (Department of Energy, 2005).

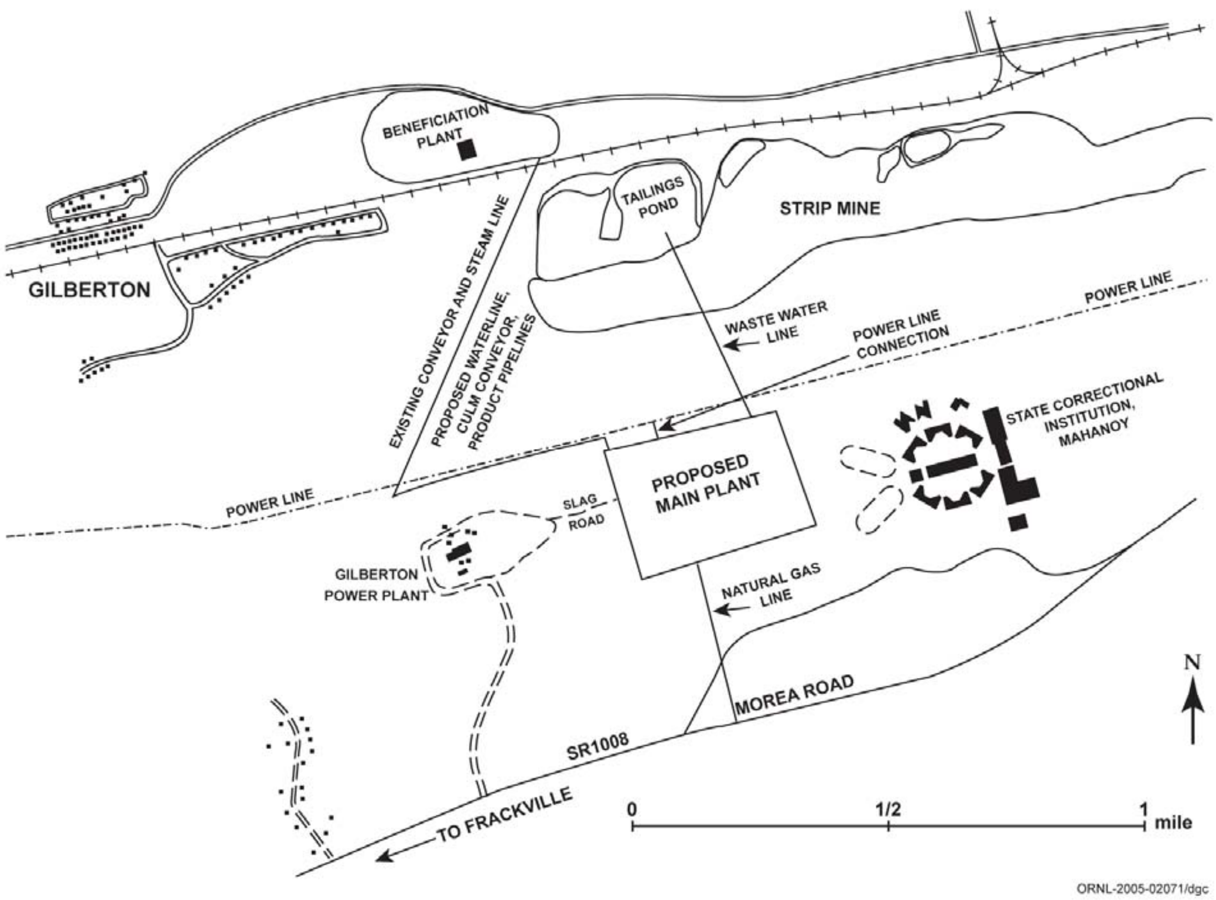


Figure VI.1. The land topology of the Gilberton FT/Power Plant (Department of Energy, 2005)

The coal culm used as the primary feedstock for the Gilberton plant will need to be washed and treated prior to gasification, which may require more land than when regular bituminous coal (the type of coal available in southwest Indiana) is used as feedstock. We estimate that a FT plant using bituminous coal as feedstock and with a capacity of 10,000 bpd of FT fuels plus a small net power export of about 50 MW, will occupy 120 acres plus another 10 acres if CO_2 capture is required. This estimate assumes that the area for coal culm wash and treatment at Gilberton will not be needed, and that space for temporary facilities during construction should not be considered part of the long-term land requirement. After one deducts these two parcels of land from the Gilberton main plant footprint, the remaining land is no more than 60 acres. We double this area to account for the doubling of capacity from 5,000 bpd to 10,000 bpd base plant.

If SNG co-production is included, land use will increase. The Dakota Gasification SNG plant has an area of about 500 acres for the main plant, with a daily coal input of about 18,500 tons (lignite) and a daily output of about 165 million standard cubic feed (scf) of SNG. The SNG plant also has an ammonia plant and a condensate plant, which occupies roughly 10% of the land. Thus, a preliminary estimate of land use per million scf SNG may be obtained as follows, If no ammonia or liquor plants are included, the main plant for SNG production with CO_2 capture may be: 500 (0.9)/165 = 2.7 (acres per million scf).

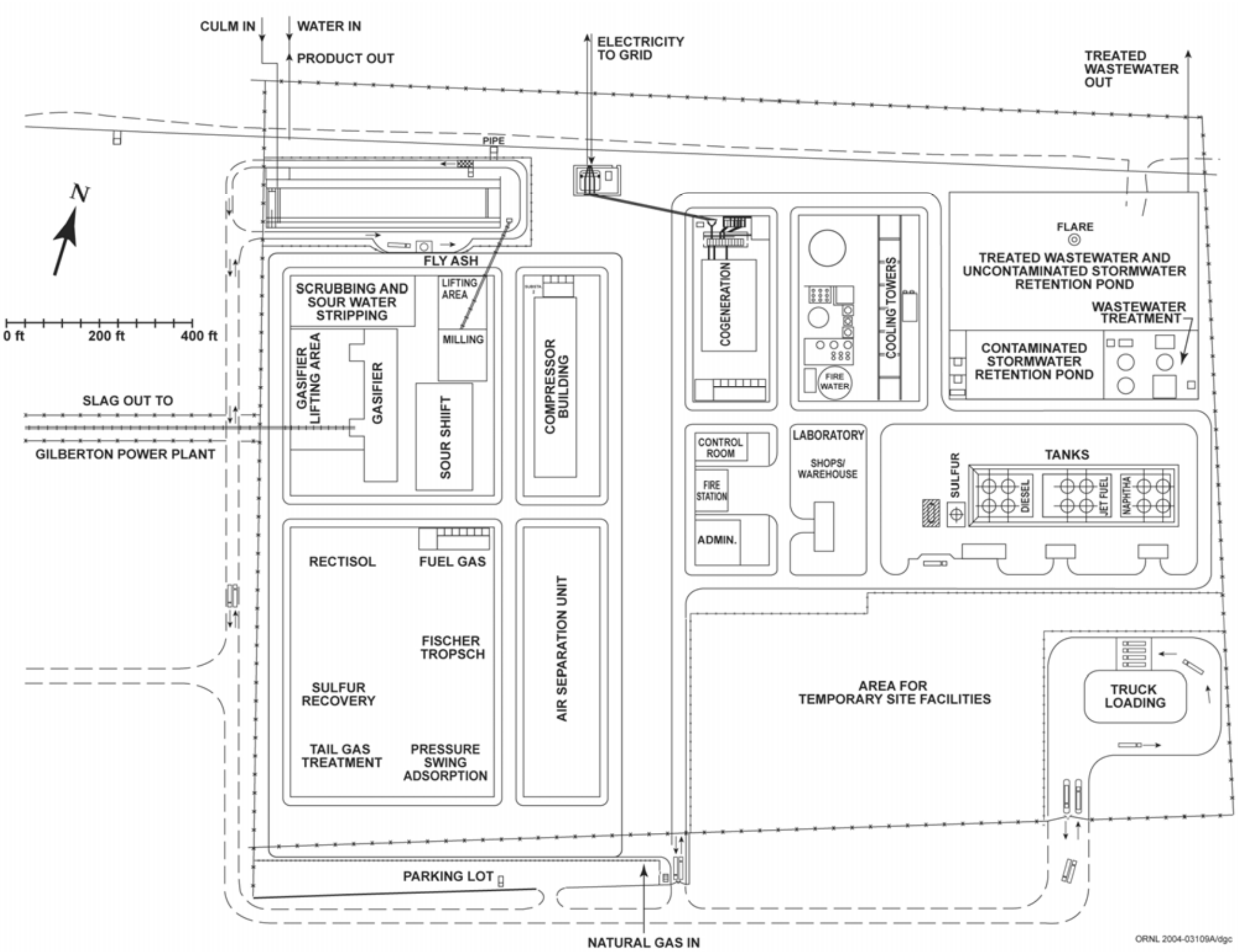


Figure VI.2. The footprint of the Gilberton FT/Power Main Plant (Department of Energy, 2005)

VI.2 Coal storage and handling

A significant land area is needed to allow inventory management of coal. To allow adequate space for a coal reserve to ensure continuous plant operation and for handling of coal, we estimate a requirement of about 20 acres for a 10,000 bpd plant. The exception to this rule is for mine-mouth sites where the coal reserve may be substantially reduced and the total is estimated to be about 10 acres.

VI.3 Landfill

Slag/ash disposal requires the lion's share of the land. However, unlike the main plant and coal storage and handling areas, the waste disposal area does not require flat land. In fact, valleys may be better sites for slag/ash disposal than flat land since they can accommodate more volume. A synfuel plant of about 10,000 B/D plus about 50 MW of net power export would use about 5,500 tons per day of bituminous coal with an ash content of about 13-15%. This means that daily production of slag/ash would be no more than 1,200 tons, assuming about 3% of the carbon in the coal ends up in the slag. If the plant's life is 25 years and the availability of the plant is assumed to be 90%, the total slag/ash generated will be around 10 million tons. Assuming that one acre of flat land can hold about 30 thousand tons of slag/ash (about two tons per square yard), the synfuel plant will require about 330 acres for landfill, assuming the slag is not sold or given away.

If the synfuel plant has a capacity of 40,000 bpd, plus over 100 MW of power export, flat land required for slag/ash disposal would increase to around 1,300 acres. Landfill area is significantly less than 1,000 acres if valleys or ponds are used. These estimates are preliminary since the actual geographical form of the land will make a large difference in its holding capacity for the slag/ash. No matter how much land is required, however, it can ultimately be restored and used for other purposes because the slag/ash underneath is inert.

If SNG is included in the output mix, then the slag/ash production should be estimated based on the coal input. That is, regardless whether FT liquids or SNG is the primary product, a plant with a coal input of about 20,000 tons per day will produce about 2,000 tons per day of slag/ash. This is because the slag/ash is produced primarily at the gasification stage, and the gasification step is quite similar regardless of whether FT liquids or SNG is the primary product.

VI.4 Cooling pond

The synfuel park may need a tailing pond to further cool water blow down, especially if some hot water blow down cannot be fed into one of the cooling towers. The cooling pond issue will be discussed further in section VII on waste disposal and environmental issues.

VI.5 Final product storage

The planned Gilberton plant design includes small scale FT liquids storage tanks. A few large storage tanks for holding FT liquids up to a few days may be needed. Their purpose is to hedge against the risk of transportation uncertainty. The land requirement for this type of storage will depend on the perceived risk of supply chain problems and may be in the range of a few acres. Ideally, the storage tanks should be separated from the main plant for safety and security reasons. Outputs of SNG and CO_2 are typically exported from the site via pipeline without storage.

VII. Environmental Concerns with Synfuel Parks/Polygeneration Plants

Environmental issues may include emissions of greenhouse gases (GHG), gaseous sulfur compounds (Sox), gaseous nitrogen compounds (NOx), mercury (Hg), and particulate matter (PM), as well as generation of waste water and slag/ash. Because of its importance as a greenhouse gas, CO_2 and its sequestration will be discussed in more detail for each site. In this section, we focus on environmental issues common to all sites under investigation.

A synfuel park can produce three categories of waste: (1) waste water, (2) gaseous emissions and (3) solids. Disposal of these wastes and the associated environmental issues are discussed separately below. It should be noted that the precise composition of the waste from a synfuel plant with power co-production is not fully known. However, the likely waste products can be inferred based on public information regarding existing IGCC, FT and SNG plants in the U.S. and elsewhere.

VII.1 Waste water

Waste water can be classified as a plant effluent. Water blow down from the cooling towers and boilers(s) is relatively clean, and provided that the blow down temperature meets the standards set by the Indiana Department of Environmental Management (IDEM), it may be released into streams either directly or after minor treatment.

However, sour water from the plant must be treated. Sour water may be blown down from the gasification island, the syngas wash/quench, and/or the humidifier before the gas turbine. Sulfur and other pollutants in the waste water can be removed, and the percentage of removal depends on the characteristics of the waste water treatment plant. A recent DOE study claims that the waste water from a FT plant can be recycled back to the cooling tower (Department of Energy, 2007). In this case, the need for waste water disposal would be greatly reduced. Of course, some solid waste and sludge is produced from the bottom blow down of the boilers and other facilities. However, they can be removed, treated and disposed of according to Federal and State regulations.

Complete treatment and recycling of waste water may incur higher cost. An alternative is to dispose of the waste water after it is treated and meets regulation standards. This is what is planned for the 5,000 bpd FT plant with co-production of power in Gilberton, PA. According to the Department of Energy (2005), the Gilberton FT plant will have a total effluent of about 1,867 gallons per minute, about 47% of which is cooling tower blow down (see Table VII.1). This estimate is higher than would be the case for a similar size plant in Indiana where bituminous coal is the feedstock. This is because the Gilberton plant is designed to use coal culm, which must be washed before gasification, as the feedstock.

Table VII.1. Water balance in the Gilberton FT/Power Plant (Department of Energy, 2005)

Plant and processes		Cooling tower		Total rate (gpm)
Source or fate	Rate (gpm)	Source or fate	Rate (gpm)	
Water supplied (from mine pool)				
Pumped for process supply	1,032	Pumped for cooling tower supply	2,744	
Supplied to coal beneficiation plant	386			
Total	1,418		2,744	4,162
Consumption and losses				
Boiler feedwater deaerator vent	1	Evaporation and drift loss	1,757	
Gas turbine steam injection	161			
Net process consumption and losses	372			
Subtotal	534		1,757	2,291
Effluent discharged to tailings pond				
Mine pool water treatment purges	381	Water treatment purge	110	
Demineralizer regeneration wastes	9	**Cooling tower blowdown**	877	
Stripped sour water	28			
F-T wastewater	124			
Rectisol purge water	36			
Gasifier water purge	106			
Polisher regeneration wastewater	6			
Recovery condensate purge	109			
Boiler blowdown	43			
In-plant wash water and floor water	38			
Subtotal	880		987	1,867
Effluent discharged to septic system				
Domestic sewage	4			4
Total consumption, losses, and wastewater	1,418		2,744	4,162

If the plant effluent is to be discarded instead of recycled to the cooling plant immediately after treatment, and if the water temperature is higher than permitted by the Indiana Department of Environment Management (IDEM) for direct discharge into a stream, a pond may need to be dug for effluent cooling. IDEM's regulations on the temperatures of the waste water for disposal vary by season (Welcome to IDEM, n.d.). Alternatively, the treated effluent could be cycled through an additional cooling system prior to discharge into a stream.

There is no experience in the U.S. with the quality of waste water from a FT plant. However, an earlier study (Rardin et al., 2005) found that waste water from the Wabash IGCC power plant meets state and federal specifications (see Table II.2). The FT plant does not add substantial impurities to the waste water because the syngas feed to the FT plant is very clean and the FT catalyst is recovered. In addition, the treated effluent can be reheated for steam use, as is commonly done in the Sasol FT plants in South Africa.

Table VII.2. Wabash River IGCC Waste Water Discharge (Rardin et al., 2005)

PARAMETER/ CONSTITUENT	UNIT	PERMIT LEVEL MONTHLY AVERAGE	PERMIT LEVEL DAILY MAXIMUM	1997 MONTHLY AVERAGE	1998 MONTHLY AVERAGE	1999 MONTHLY AVERAGE
Ammonia (as Nitrogen)	mg/l	27.14	54.29	3.93	6.56	8.8
Arsenic	mg/l	0.018	0.043	0.0077	0.0199[a]	<0.01
Cadmium	mg/l	0.010	0.025	<0.0038	<0.008	<0.01
Chromium	mg/l	3.47	8.07	<0.006	<0.0108	<0.0167
Hexavalent Chromium	mg/l	0.014	0.032	<0.01	<0.0120	<0.01
Copper	mg/l	0.040	0.093	<0.01	<0.0145	0.0185
Cyanide	mg/l	0.019	0.044	0.107[a]	0.2798[a]	0.1438[a]
Lead	mg/l	0.260	0.606	<0.08	<0.08	<0.08
Mercury	mg/l	0.0005	0.001	<0.005	<0.0005	<0.0006
Nickel	mg/l	2.91	6.78	<0.02	<0.0236	<0.1140
Selenium	mg/l	0.017	0.040	0.0714[a]	0.230[a]	0.1380[a]
Zinc	mg/l	0.241	0.560	0.05	0.0414	0.1363
pH	mg/l	6.0 to 9.0	6.0 to 9.0	7.99	8.4	7.5

[a] Originally out of permit compliance, but later corrected

The U.S. has a long history of operating a SNG plant – the Dakota Gasification Company SNG plant (Department of Energy, Office of Fossil Energy, 2006). Waste water disposal from that plant has met the regulatory standards. These observations suggest that synfuel parks can be designed to meet regulators' standards for waste water disposal.

VII.2 Air emissions

A synfuel park like the one illustrated in Figure I.1 has never been constructed. However, there is a large CTL (coal to liquids) FT plant in South Africa - the Sasol Secunda Plant. In addition, there are several IGCC and SNG plants (Rardin et al., 2005). From these plants, air emissions for a synfuel park can be inferred.

Since the composition of the emissions from the Secunda Plant has not been made public, the likely air emissions from a U.S. FT plant are not known precisely. However, if the FT plant includes co-production of power with an IGCC generator, air emissions can be estimated based on current IGCC performance, plus some allowance for the FT unit.

The Great Plains Synfuel Plant in North Dakota mainly produces SNG (substitute natural gas), with liquids produced only as byproducts (Figure VII.1). In this plant, acid gases are sent to the plant's Riley Stoker boilers, and a Flue Gas Desulfurization (FGD) unit is used to scrub the flue gas from the boilers. The scrubbing section of the FGD unit uses ammonia rather than limestone to scrub the SO2, which produces ammonium sulfate. The ammonium sulfate crystals are sent to a dewatering and compaction section to produce ammonium sulfate granules. The granules meet the specifications for fertilizer-grade ammonium sulfate, and about 110,000 tons are marketed annually as Dak-Sul 45. The resulting air emissions meet EPA's standards.

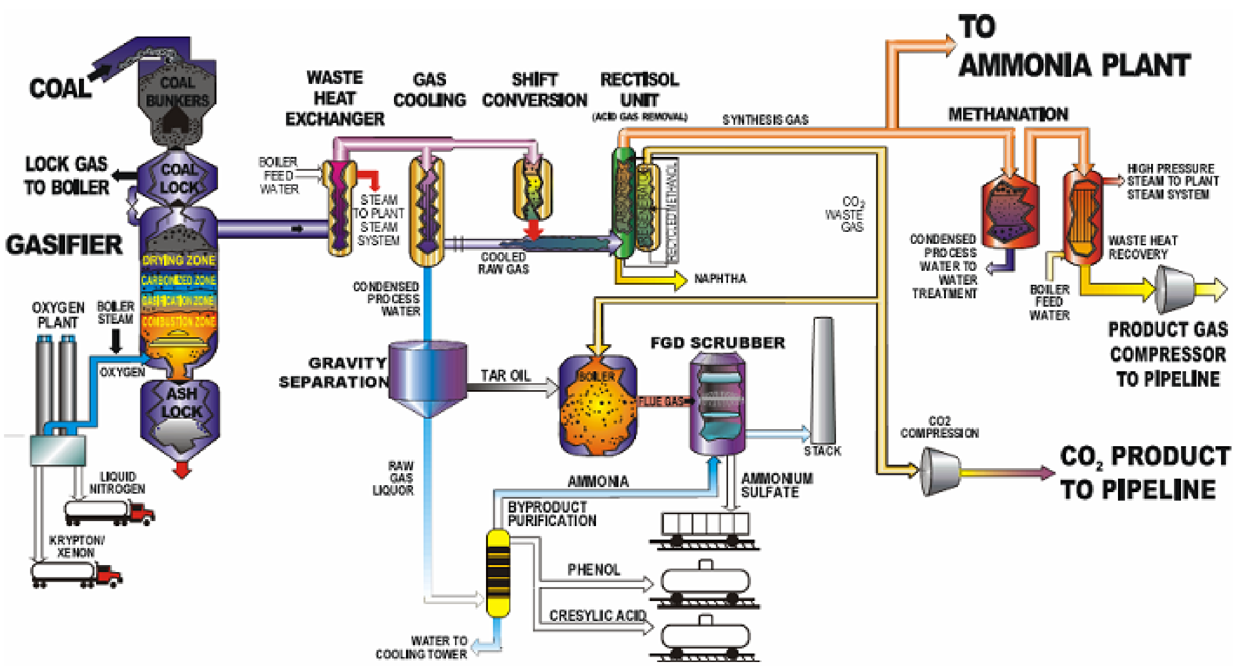


Figure VII.1. Flow diagram of the Great Plains SNG Plant (Department of Energy, Office of Fossil Energy, 2006)

VII.2.1 IGCC and SNG plant air emissions

An earlier study (Yu, Black, and Rardin, 2005) summarized the air emissions from some IGCC power plants, listed in Table VII.3 below. Note that the Wabash, TECO, and Pinon Pine IGCC power plants are demonstration plants that have been in commercial operation for the last few years. The others are either proposed or under development. IGCC plants such as the one proposed by Duke Energy Indiana for Edwardsport are expected to have air emission performance similar to the Mesaba plant (Figure VII.2).

Note that the mercury (Hg) emission level from an IGCC is in the range of 5-10% of the mercury contained in the coal that fuels the plant (Indiana Department of Environmental Management, 2007). This emission level actually out performs IDEM's requirement of 30% or less (Lynch, 2005).

In general, technologies based on coal gasification are superior in air emission performance to pulverized coal (PC) technologies. However, new power plants, even those based on the supercritical pulverized coal (SCPC) and ultra SCPC technologies, can also have excellent air emission performance (see Figure VII.2 and Lynch, 2005).

Table VII.3. Air emissions of the US IGCC Plants – Existing and Proposed (Yu et al., 2005)

Plant	SO2	Nox	Carbon monoxide	Volatile Organic Compounds	Hg
Wabash IGCC	99% or <0.1 lb/mmBtu	<25 ppmv or 0.15lb/mmBtu or 1.09lb/MWh	0.05 lb/10^6, well below industry standards	n/a	n/a
Wabash-I	Similar to the above	Similar to the above	Similar to above	n/a	n/a
TECO Polk IGCC	>99% or 29lb/hr	15 ppmv or Average 0.7lb/MWh	n/a	< design limit	n/a
Sierra Pacific Pinon Pine IGCC	>95%	50% less conventional coal plants	20% less conventional coal plants	n/a	n/a
EKPC-Kentucky	0.032 lb/mmBtu	0.072 lb/mmBtu	0.032 lb/mmBtu	0.0044 lb/mmBtu	0.08 mg/dscf (EPA data)
Mesaba – Hoyt Lakes	0.022lb /mmBtu	0.058lb /mmBtu	0.03lb /mmBtu	0.002lb /mmBtu	4.3E-6 lb /mmBtu

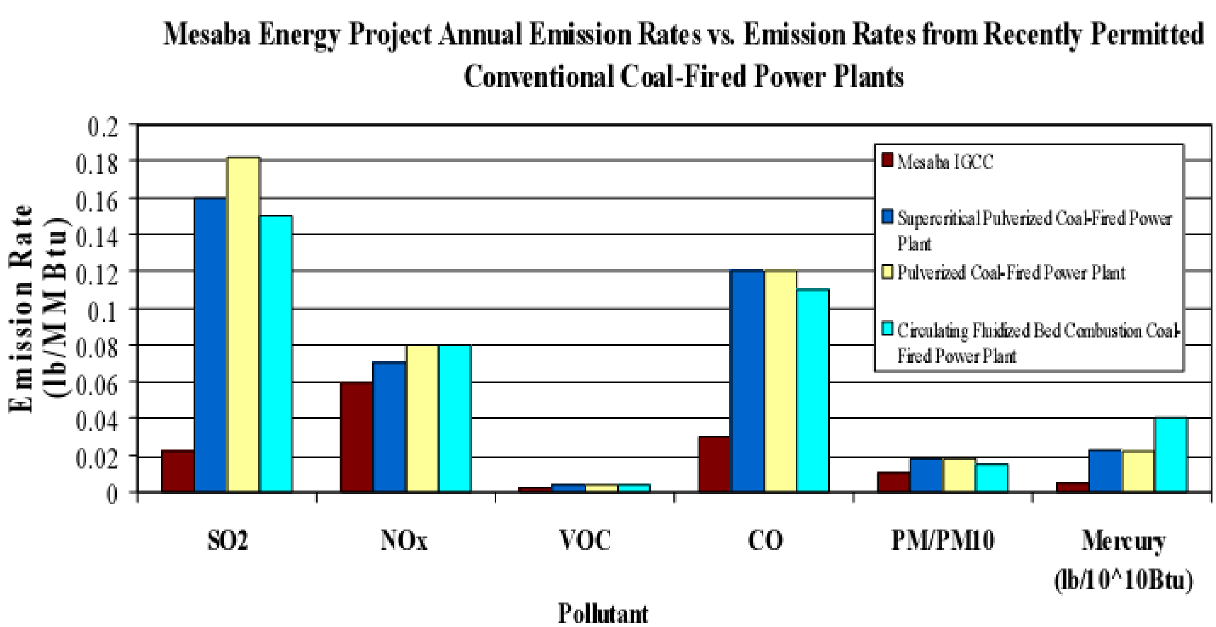


Figure VII.2. Comparison of emissions between IGCC and other power plants (Yu et al., 2005)

VII.2.2 CO_2 Capture in IGCC and SNG plants

Several technologies are available for extracting CO_2 from IGCC and SNG plants. These include the two-stage Rectisol system, the Selexol process, and the amine acid gas removal process. Both the Rectisol and Selexol systems are based on physical solvents, while the amine acid gas removal process involves chemical solvents. The processes based on physical solvents are generally more expensive than those based on chemical solvents; they are also more efficient. The physical solvent processes depend upon high pressures and/or temperatures. SNG and IGCC power plants with coal gasification are well designed to capture CO_2 because the syngas stream is under high pressure and has a high CO_2 concentration.

According to Lynch (2005), Rectisol can capture 90-95% of the CO_2 in the syngas stream. One commercial project capturing CO_2 from syngas production is the Great Plains Synfuel Plant in North Dakota, where CO_2 is captured and transported via a 200-mile pipeline to the Weyburn oil field in Saskatchewan, Canada (Perry and Eliason, 2004) (see Figure VII.3) where it is used for enhanced oil recovery. According to Perry and Eliason, the Rectisol unit at the Great Plains Synfuels Plant already produces a 95% pure CO_2 stream due to the nature of the process. It is also "bone-dry," with a dew point of -100º F, because of the cold methanol absorption and regeneration processes used to remove the CO_2 from the product gas stream.

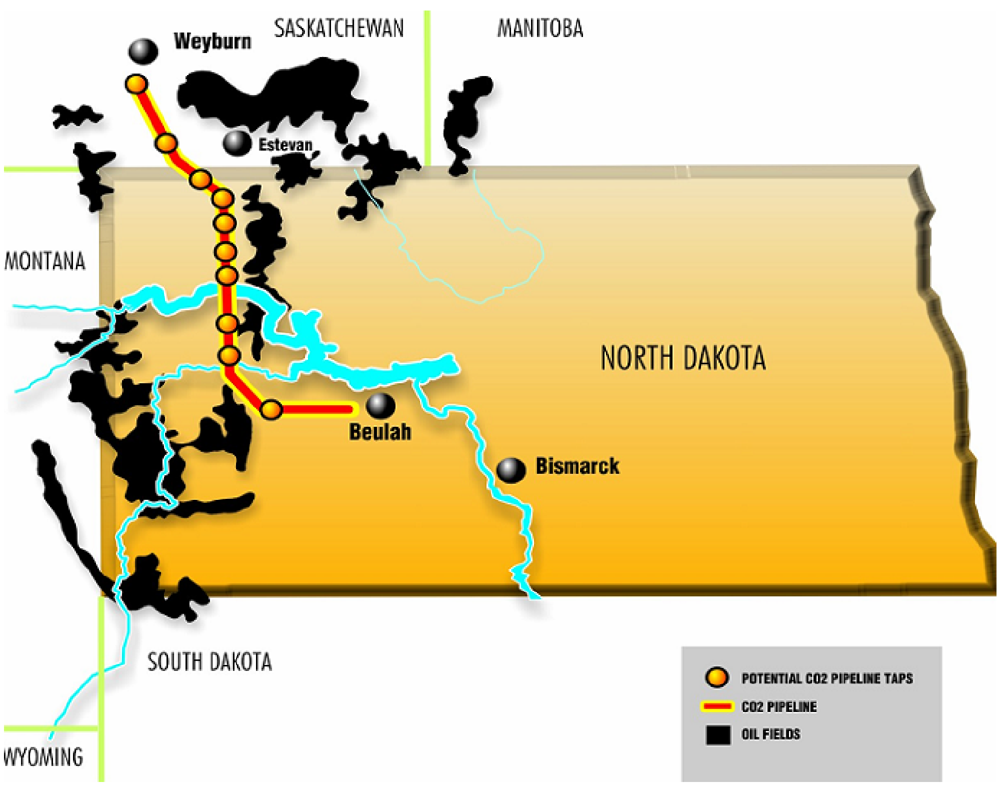


Figure VII.3. Topology of the EOR using the CO_2 captured in the Dakota SNG Plant (Perry and Eliason, 2004)

Another commercial CO_2 capture project in the U.S. is smaller in scale – the ammonia plant in Coffeyville, Kansas, owned by Farmland Industries (see Figure VII.4). At this facility, petcoke, which has a much higher sulfur content than bituminous coal, is the primary feedstock. Instead of a Rectisol unit, as in the case of the Great Plains Synfuels Plant, the Selexol process is used for sulfur and CO_2 removal. Part of the separated CO_2 is used to manufacture fertilizer, with the excess vented to the atmosphere. These plants demonstrate that CO_2 removal technologies are commercially viable.

Figure VII.4. Coffeyville Ammonia Plant with CO_2 Capture (Sharp, Kubek, Kuper, Clark, and DiDio, 2002)

VII.2.3 Air emissions from the FT portion of the plant

Sulfur, nitrogen oxides (NOx), mercury (Hg), and particulate matter (PM) are removed from syngas before it is fed to the FT plant, so these emissions do not present problems in the downstream FT process. In addition to the methane traces in the syngas, traces of methane, which could be regarded as a greenhouse gas, may be released from the FT process. We do not know exactly how much methane would be released from the FT plant, and further studies would be needed to assess this issue. However, we do not think it will be a serious problem, because the tail gas from the FT plant can be fed to the gas turbine in order to burn the methane. CO_2 will be generated in the FT process and present in the tail gas. It can be removed through the traditional absorption method by the use of amine solvents.

In general, we are not aware of any problems due to air emissions in obtaining permits for a FT plant with co-production of power. In a draft study for the planned Gilberton FT plant in Pennsylvania, the environmental issues with the plant were assessed by the local authority and the U.S. Environmental Protection Agency (Department of Energy, 2005). The general conclusion was that there would be no serious problems with air emissions.

VII.2.4 Air emissions from the SNG section

In converting the clean syngas to SNG in the methanation section, CO_2 will be generated in the water-gas shift (WGS) reaction. (For the optimal methanation reaction to occur the CO to hydrogen ratio should be around 3:1, as described by Jenkins, 2006). Hence, it may be necessary to capture the CO_2 in the methanation process. This has been done in the Dakota SNG plant as described above. There can be unconverted CO in the SNG stream, and the CO will have to be captured as well. However, since the Dakota SNG plant has done so successfully, this does not seem to be a problem.

VII.2.5 Air emissions from the syngas gas turbine

If the syngas is fed directly to the gas turbine for power production, CO_2 will be produced in the turbine exhaust after the syngas is burned with oxygen. The CO_2 can be captured using various methods, such as the amine technology. In order to control NOx formation in the gas turbine, either nitrogen from the air separation unit (ASU) or steam can be fed to the turbine.

VII.2.6 Air emissions from the hydrogen turbine

If hydrogen is used for power production, there will be no emission problems since hydrogen forms water vapor after combustion with oxygen in the air. This scheme, the so-called zero emissions strategy in power production, is the target of the FutureGen project, to be implemented by DOE through public & private partnerships.

VII.3 Solid wastes

VII.3.1 Slag/ash

The primary solid waste from coal gasification when very high temperature, high pressure gasifiers are used is slag – ash is secondary. In 2003, EPA issued a regulatory document on the New Source Performance Standards (NSPS), in which Subpart Da sets Standards of Performance for Electric Utility Steam Generating Units (2007). In this document, slag from coal gasification is covered as a “mineral processing waste” if the coal feed is greater than 50% of the feedstock (Jenkins, 2006). This classification means that permission to dispose of slag in a landfill is not too difficult to obtain. Slag is inert, and the landfill can be beautified and used for other purposes.

In addition, slag can be used for making cement, asphalt fillers and roofing shingles, as well as for building sports fields and roads. Thus, some extra revenue can be generated by selling the slag byproduct.

VII.3.2 Sulfur

Using current technologies, more than 99% of the sulfur in coal can be recovered in the FT and power plants. If 6,000 tons of coal with a sulfur content of 3% are used each day (corresponding to a 10,000 bpd FT plant), approximately 180 tons of pure sulfur will be produced. Sulfur is recovered using a Scott/Clause system, and can be sold for fertilizer production and industrial processes.

VII.3.3 Carbon beds

Carbon beds can contain significant concentrations of mercury and are hazardous. While the volume of the carbon bed materials produced will be low relative to the slag and ash, they will need to be disposed of by a professional waste management firm.

VII.4 Sludge and oil

Iron sludge, wastewater sludge, spent catalyst sludge, oil and other organic compounds will need to be separated and removed. Oil/water separators, air flotation units, and biological reactors can be used for this purpose. This type of water treatment process neutralizes the water to a pH of 7, as reported by the Department of Energy's Office of Fossil Energy (2006) and the Department of Energy (2005). Oil recovered by an oil/water separator would be directed to a used oil storage tank and ultimately removed by a contractor for recycling and/or disposal.

VIII. Labor Requirements

The National Energy Technology Laboratory (NETL) estimates 144 direct operations personnel for a 50,000 barrel per day (bpd) plant. Administrative, maintenance and other support personnel are likely to add another 40-50 percent, or another 58-72 positions. The scaling of the labor needs is probably non-linear, with smaller scale operations requiring more labor per barrel of capacity.

Many of the jobs will be of a new genre (e.g., gasifier operators), and training will present a challenge. However, there are several educational resources in the area, including Purdue University, Indiana University, Vincennes University, Ivy Tech and Indiana State University. In addition, the Wabash Valley Power Association's IGCC plant could serve as a training facility.

IX. Economic Impact

While the number of jobs created directly by locating a synfuel park in southwest Indiana is modest, the economic impact would be substantial. NETL estimates revenues (including power export) on the order of about $80 per barrel of FT liquids. Even for a small plant (i.e., 10,000 barrels per day) running at a 90 percent capacity factor, this amounts to revenues of three quarters of a million dollars per day. The indirect impact would be much larger through the economic multiplier effect, which is particularly high for the coal mining sector.

The counties in the study area generally have unemployment rates that are higher than the state average (with the exceptions of Daviess and Dubois), and per capita income for these counties is generally lower than the state average (with the exceptions of Dubois, Posey, Vanderburgh, and Warrick). Thus, there is substantial need for economic development in this part of the state and the potential contribution of a synfuel park in the area is large.

More information regarding the economic impact of synfuel park/polygeneration plants can be found in Irwin et al. (2007).

X. The Francisco Mine

The Francisco Mine includes both surface and underground mining operations with a combined annual production of around 3 million tons of coal. The site is located in Gibson County, about 25 miles north of Evansville and 8 miles east of Princeton. The Norfolk Southern rail runs by the site, and the Indiana Southern rail lines run north-south a few miles to the east?/west? of the site. The Patoka River is just a few miles to the north of the site. A detailed map of the supporting infrastructure is shown in Figure X.1.

X.1 Coal availability

Coal is available at the mine, and the coal is of a quality and type that is good for synfuel production. As reported by Drobniak, Mastalerz, and Shaffer (2006), coal can be obtained not just from the Francisco Mine, but also from some other large mines nearby, such as the Somerville #1 pit (#8 on the IGS map), the Discovery #1 (#2 on the IGS map) and several others, as indicated in Table X.1. Overall, the site is the best among those considered in terms of coal availability.

Table X.1. Coal Production of Mines at and near Francisco (Indiana Coal Council, n.d.)

Mine Name	Year Opened	Tonnage (2006)	Location
Francisco	1996	1,989,230 (surface) 3,147,515 (Total)	Gibson County
Somerville (2 mines)	1993, 1996	8,551,987	Gibson County
Gibson County Coal	2000	3,551,200	Gibson County
All mines in Pike	Various	1,729,639 (surface) 2,777,562 (underground)	Pike County, near Francisco

X.2 CO_2 sequestration potential

At the Francisco site, there are four options for geological sequestration of CO_2 from a gasification facility: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production and injection into deep saline water-filled aquifers.

Detailed results of our quantitative assessment are presented in Appendix E, Section.2. It appears that 302 million scf of enhanced coal bed methane could be produced with a potential storage of over 13 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 212 million standard barrels (stb) of crude oil and the potential to sequester 47 million tons of CO_2. Over 2.6 billion scf of enhanced shale gas could potentially be recovered with the flooding of about one billion tons of CO_2. Injection into deep saline water-filled aquifers has potential for the sequestration of another 414 million tons. Thus, there are several potential options for geological sequestration of CO_2 in the Francisco area, with the greatest potential capacity in shale deposits and deep saline-filled aquifers.

Figure X.1. Infrastructure of the Francisco area

X.3 Transportation infrastructure/logistics

Transportation infrastructure is required for: (1) shipment of large components of the synfuel plant (mainly the gasifier(s), FT reactors, raw syngas cleaning, and liquids upgrading equipment) during construction, (2) the transportation of coal to Francisco, and (3) the distribution of finished products. These issues are discussed separately below.

X.3.1 Shipment of large pieces of equipment to Francisco

As indicated in the section on regional transportation infrastructure (Section IV.1.1), the likely mode of delivery for large equipment is to a port on the Ohio River. Once it is unloaded either at Jeffboat or Mount Vernon, the best strategy for delivery of large equipment will be via rail. Several rail line overpasses have been built on the route from Jeffersonville to Francisco. In addition, there is a tunnel between these two destinations. These facts make the rail route from Jeffersonville to Francisco unfavorable. Mount Vernon is in the southwest corner of Indiana, also on the Ohio River. There are two rail routes connecting Mount Vernon and Francisco. However, there are also overpasses on these two routes, as shown in Tables X.2 and X.3. Therefore, the costs and benefits of different sized reactors and arrangements for shipment need to be assessed jointly in order to determine the best strategy for shipping components to Francisco. The relevant sections of rail track are owned by CSX and the Norfolk Southern (NS) companies, and a definitive opinion regarding the feasibility of shipping large equipment would depend upon its precise dimensions and weight.

Table X.2. Overpasses and bridges from Mount Vernon through Evansville to Francisco (Appendix B)

Routes	# of overpasses	Intersection with roads or rivers	Location
From Evansville to Baldwin Heights (Princeton) through CSXT Rail	1	West Lloyd Expressway	Evansville
	2	West Delaware St.	Evansville
	3	IN-66	North of Evansville
	4	Darmstadt Rd	North of Evansville
	5	Old State Rd	North of Evansville
	6	I-64	South of Haubstadt
	7	US-41	South of Princeton
	8	US-41 Parallel	South of Princeton
From Baldwin Heights (Princeton) to Francisco through the NS Rail	9	S Main Street	South Princeton

Table X.3. Overpasses and bridges from Evansville to Francisco through shortlines

	#	Intersection with roads or rivers	Location
From Evansville to Oakland City	1	Bridge	Evansville
	2	I-164	Northeast of Evansville
	3	I-64	Northeast of Elberfeld
	4	Cr 450 S	Northeast of Somerville
From Oakland City to Francisco	5	IN-57	West of Oakland City

X.3.2 Transportation of coal to Francisco

If the coal feedstock is sourced from the Francisco Mine, it can be transported to the nearby synfuel park either by truck or conveyor. If coal is taken from other mines in the surrounding area, both rail cars and trucks can be used. Thus, coal transportation to a synfuel park in the Francisco area is very simple..

X.3.3 Transportation of finished products from Francisco

The primary finished products of a synfuel park are likely to be FT diesel, gasoline, military fuel(s), naphtha, SNG and/or hydrogen. Sulfur is a byproduct that can be sold or given away for use in fertilizer production. These products can be shipped via rail. Francisco is connected via the NS and CSX rail systems, which are in turn connected to the Ohio River. State highways can also be used for small quantities of product shipment.

X.3.4 Transportation of slag/ash from Francisco

Emptied strip mines, to which slag/ash can be trucked, may be economically attractive for slag/ash disposal. Such areas are scattered near Francisco; they correspond to the gray areas to the east of the town, shown above it in Figure X.2.

X.4 Water requirements and resources

For a FT plant with electricity co-production, water requirements depend on many factors, including capacity, choices in the design of the cooling tower, power output, coal type etc. If wet, evaporating cooling towers are used, 10-15 bpd of water may be required per barrel of FT liquids. For an equivalent energy basis of coal input, SNG production requires about 30-40% more water than FT production. According to a Rentech study, reduced water use is possible through water conservation and more efficient design (Rentech Projects, n.d.). In fact, dry cooling systems could be used, which would reduce raw water use significantly.

X.4.1 Water resources from the Patoka River

The Patoka River is about 1-2 miles from the Francisco Mine (see Figure X.2). The river is fed by the Patoka Lake, plus some small creeks. Table X.4 lists the average stream flow from the monitoring station at Winslow, which is a few miles down stream from Francisco, and Table X.5 shows the average stream flow at the monitoring station at Patoka City, about 10 miles upstream from Francisco. There is no monitoring station at Francisco, so a distance weighted average of the stream flow data from the two existing monitoring station was used to estimate the average flow near Francisco, as shown in Table X.6.

The flow of the Patoka River near Francisco is limited in late August through October, as shown in Tables X.4-6. The lowest average flow rate is in September, with an estimated value of 177 cfs (Table X.6). The hydrograph of water flow over time near Francisco is shown in Figure X.3.

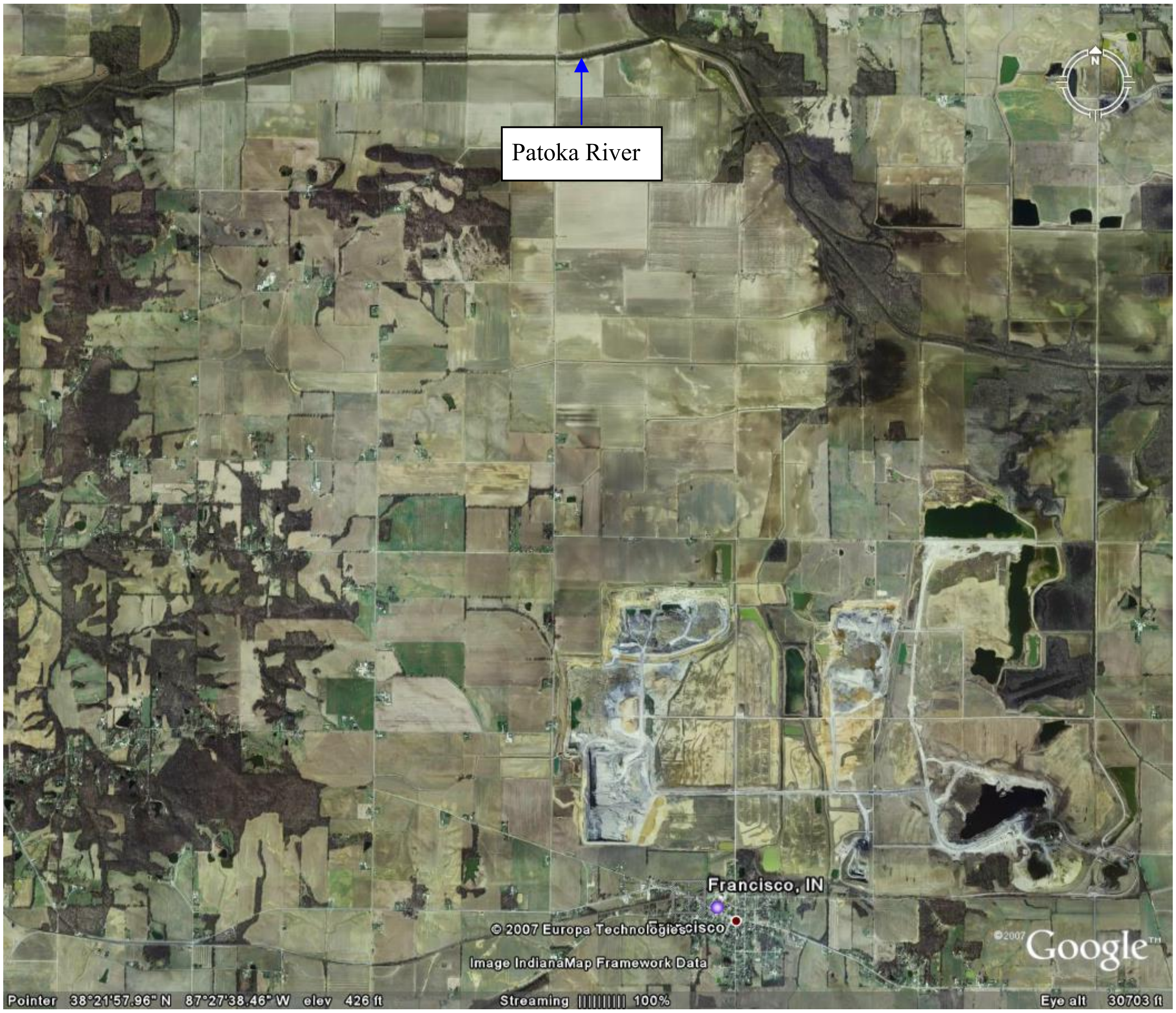


Figure X.2. Land topology in Francisco area (Google Earth, 2007)

Table X.4. Average Patoka River stream flow at Winslow (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	Mean of daily mean values for each day for 31 - 33 years of record in cubic feet/sec (cfs) (Calculation Period 1963-10-01 -> 2006-09-30)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1,020	1,330	1,150	1,390	1,540	843	264	251	252	147	141	641
2	1,090	1,380	1,150	1,420	1,550	824	307	210	234	145	161	667
3	1,160	1,390	1,190	1,420	1,520	869	331	166	229	142	183	701
4	1,240	1,390	1,300	1,430	1,520	866	320	148	214	160.	184	721
5	1,260	1,410	1,420	1,390	1,490	812	314	158	186	173	218	706
6	1,280	1,410	1,470	1,390	1,450	807	346	169	182	158	233	666
7	1,290	1,360	1,460	1,360	1,430	860.	344	174	186	146	273	645
8	1,280	1,320	1,450	1,330	1,390	826	355	172	172	137	304	665
9	1,250	1,290	1,530	1,290	1,310	793	322	181	157	133	283	673
10	1,210	1,340	1,720	1,260	1,220	748	332	205	158	153	297	715
11	1,120	1,290	1,770	1,200	1,170	686	370.	232	156	167	327	745
12	1,050	1,260	1,880	1,170	1,070	655	395	219	174	166	389	772
13	992	1,260	1,970	1,170	1,080	680	447	181	203	167	377	753
14	998	1,340	2,010	1,180	1,090	665	411	155	181	170	418	750
15	985	1,390	1,980	1,200	1,100	588	389	145	174	177	444	757
16	945	1,460	1,930	1,370	1,110	516	393	146	213	170	469	758
17	919	1,460	1,840	1,440	1,130	500	361	147	244	171	504	842
18	954	1,490	1,740	1,420	1,150	467	291	140	242	174	535	895
19	1,020	1,490	1,670	1,380	1,170	401	247	130	228	194	563	964
20	1,140	1,450	1,650	1,390	1,160	372	253	135	222	178	580	983
21	1,180	1,440	1,660	1,460	1,110	356	276	179	212	177	544	980.
22	1,210	1,480	1,620	1,420	1,070	365	320	210	210	168	503	1,020
23	1,250	1,440	1,580	1,400	1,010	381	308	192	220	162	499	1,000
24	1,240	1,340	1,520	1,360	936	345	254	221	223	177	478	1,010
25	1,210	1,260	1,490	1,320	908	283	222	213	220	194	476	985
26	1,200	1,190	1,480	1,320	889	227	202	222	249	192	548	944
27	1,190	1,150	1,410	1,290	868	209	191	243	272	207	577	896
28	1,210	1,150	1,430	1,350	831	244	189	244	301	203	617	868
29	1,200	775	1,410	1,410	786	253	205	252	291	195	651	876
30	1,230		1,390	1,490	776	252	218	266	273	187	625	924
31	1,240		1,380		845		238	272		167		994

Table X.5. Average Patoka River stream flow at Patoka City (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	**Mean of daily mean values for each day for 72 - 72 years of record, in cfs (Calculation Period 1934-10-01 -> 2006-09-30)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1,290	1,890	1,840	2,130	1,750	1,010	542	447	338	223	219	883
2	1,310	1,890	1,860	2,110	1,810	991	546	421	338	222	245	890
3	1,350	1,860	1,890	2,080	1,830	978	554	400.	335	224	273	897
4	1,400	1,830	1,950	2,100	1,880	996	518	386	317	244	294	898
5	1,430	1,800	1,990	2,100	1,840	1,010	513	390	291	252	309	889
6	1,450	1,790	2,040	2,110	1,790	995	486	368	278	261	311	879
7	1,450	1,760	2,050	2,060	1,780	975	502	373	268	282	321	892
8	1,440	1,730	2,030	2,010	1,760	951	489	378	234	269	335	885
9	1,450	1,710	2,060	1,970	1,720	952	481	352	214	266	353	871
10	1,470	1,730	2,100	1,940	1,670	954	468	337	208	278	377	867
11	1,460	1,710	2,170	1,900	1,670	938	461	335	202	280	422	879
12	1,420	1,710	2,210	1,890	1,600	953	434	312	207	293	451	927
13	1,400	1,740	2,240	1,860	1,610	972	409	295	215	298	463	941
14	1,410	1,760	2,280	1,850	1,610	961	403	268	221	321	512	962
15	1,420	1,780	2,300	1,830	1,600	899	417	265	222	314	527	985
16	1,420	1,780	2,340	1,860	1,610	840	413	281	237	287	540	992
17	1,430	1,780	2,370	1,860	1,580	811	396	297	253	277	553	1,020
18	1,460	1,800	2,390	1,870	1,550	761	403	301	242	267	592	1,040
19	1,500	1,790	2,400	1,870	1,490	701	384	283	234	248	618	1,070
20	1,560	1,770	2,400	1,880	1,430	679	398	265	215	240	663	1,070
21	1,600	1,780	2,420	1,890	1,370	652	404	288	207	234	670	1,070
22	1,670	1,810	2,410	1,870	1,350	648	427	273	201	225	668	1,090
23	1,710	1,840	2,380	1,870	1,350	668	442	249	199	226	693	1,100
24	1,780	1,830	2,360	1,870	1,310	661	413	266	**196**	248	696	1,090
25	1,810	1,810	2,330	1,850	1,280	647	383	243	214	250	712	1,130
26	1,850	1,810	2,280	1,810	1,250	618	376	260	225	243	754	1,150
27	1,840	1,820	2,250	1,760	1,210	600	386	259	252	256	798	1,140
28	1,850	1,830	2,240	1,720	1,150	567	404	264	252	239	845	1,160
29	1,850	1,590	2,200	1,680	1,110	567	422	290	256	232	857	1,180
30	1,920		2,170	1,730	1,080	531	410	288	255	219	869	1,220
31	1,930		2,170		1,060		421	306		209		1,250

Table X.6. Estimated average stream flow for the Patoka River near Francisco

Day of month	**Estimated Mean of daily mean values for each day for 72 - 72 years of record, in cfs (Calculation Period 1934-10-01 -> 2006-09-30)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1,142	1,582	1,461	1,723	1,635	918	389	339	291	181	176	750
2	1,189	1,610	1,470	1,731	1,667	899	415	305	281	180	199	767
3	1,246	1,602	1,505	1,717	1,660	918	431	271	277	179	224	789
4	1,312	1,588	1,593	1,732	1,682	925	409	255	260	198	234	801
5	1,337	1,586	1,677	1,710	1,648	901	404	262	233	209	259	788
6	1,357	1,581	1,727	1,714	1,603	892	409	259	225	204	268	762
7	1,362	1,540	1,726	1,675	1,588	912	415	264	223	207	295	756
8	1,352	1,505	1,711	1,636	1,557	882	415	265	200	196	318	764
9	1,340	1,479	1,769	1,596	1,495	865	394	258	183	193	315	762
10	1,327	1,516	1,891	1,566	1,423	841	393	264	181	209	333	783
11	1,273	1,479	1,950	1,515	1,395	799	411	278	**177**	218	370	805
12	1,217	1,463	2,029	1,494	1,309	789	413	261	189	223	417	842
13	1,176	1,476	2,092	1,481	1,319	811	430	232	208	226	416	838
14	1,183	1,529	2,132	1,482	1,324	798	407	206	199	238	460	845
15	1,181	1,566	2,124	1,484	1,325	728	402	199	196	239	481	860
16	1,159	1,604	2,115	1,591	1,335	662	402	207	224	223	501	863
17	1,149	1,604	2,079	1,629	1,333	640	377	215	248	219	526	922
18	1,182	1,630	2,033	1,623	1,330	599	341	212	242	216	561	960
19	1,236	1,625	1,999	1,601	1,314	536	309	199	231	218	588	1,012
20	1,329	1,594	1,988	1,611	1,282	510	318	194	219	206	617	1,022
21	1,369	1,593	2,002	1,654	1,227	489	334	228	210	203	601	1,021
22	1,417	1,629	1,976	1,623	1,196	492	368	238	206	194	577	1,052
23	1,457	1,620	1,940	1,612	1,163	510	368	218	211	191	586	1,045
24	1,483	1,561	1,898	1,590	1,104	487	326	241	211	209	576	1,046
25	1,480	1,508	1,868	1,559	1,075	447	294	227	217	219	582	1,050
26	1,493	1,469	1,840	1,541	1,051	403	280	239	238	215	641	1,037
27	1,483	1,452	1,788	1,502	1,022	385	279	250	263	229	676	1,006
28	1,498	1,456	1,795	1,517	975	389	286	253	279	219	720	999
29	1,493	1,142	1,766	1,532	932	394	303	269	275	212	744	1,013
30	1,541	0	1,741	1,598	913	378	304	276	265	201	735	1,057
31	1,551	0	1,736	0	942	0	320	287	0	186	0	1,109

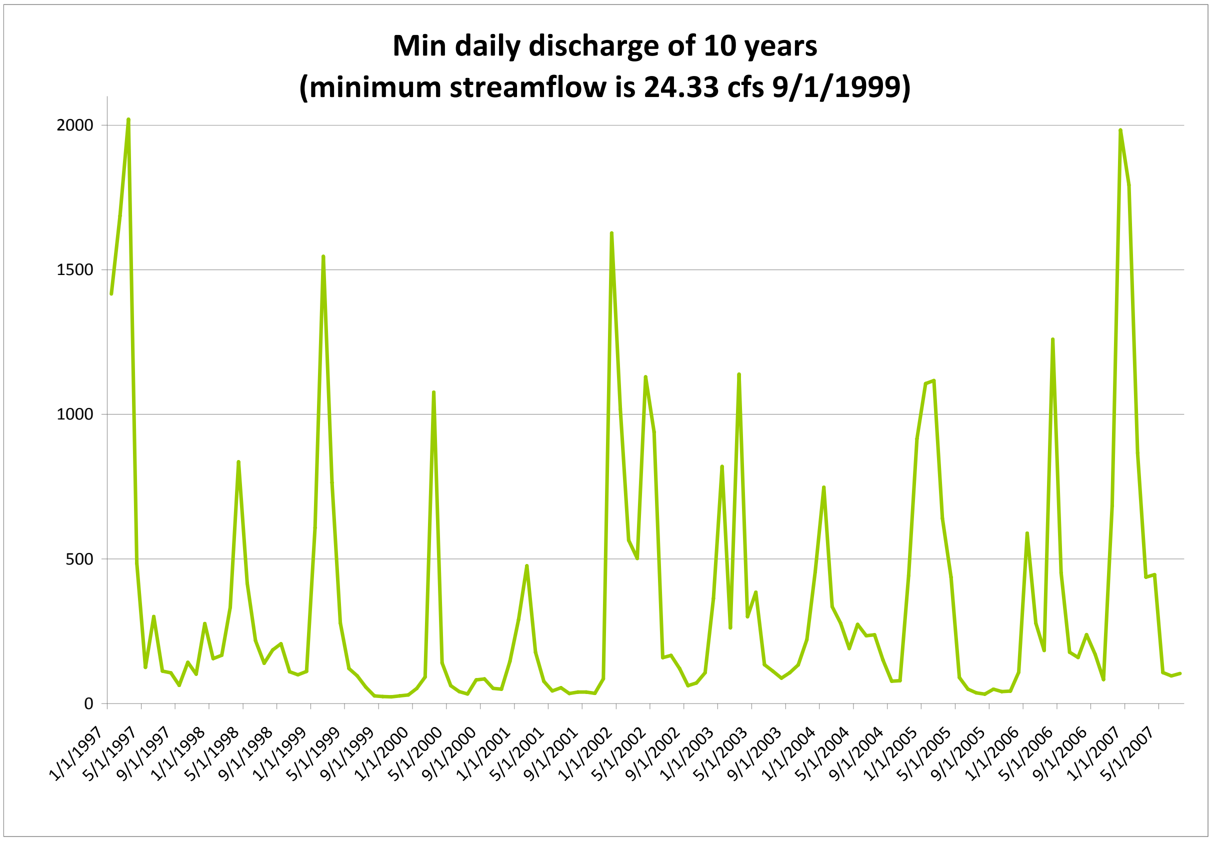


Figure X.3. Estimated minimum daily stream flow for Patoka River near Francisco

X.4.2 Underground water resources

Francisco is in the central east region of Gibson County. Underground water is not abundant in the Francisco area (Figure X.4). Each well is expected to produce only about 10 gallons per minute (gpm) on average, an insignificant amount in the context of the needed water resources. Some mine pool water is available, but the amount is still very limited.

X.4.3 Water use regulation

According to the Division of Water of the Indiana Department of Natural Resources (DNR), there are no restrictions on water withdrawal from the Patoka River, except that the withdrawal must be registered with the DNR if it exceeds 100,000 gallons per day (see Appendix C). The DNR also requires it be notified of the amount of water withdrawn per year.

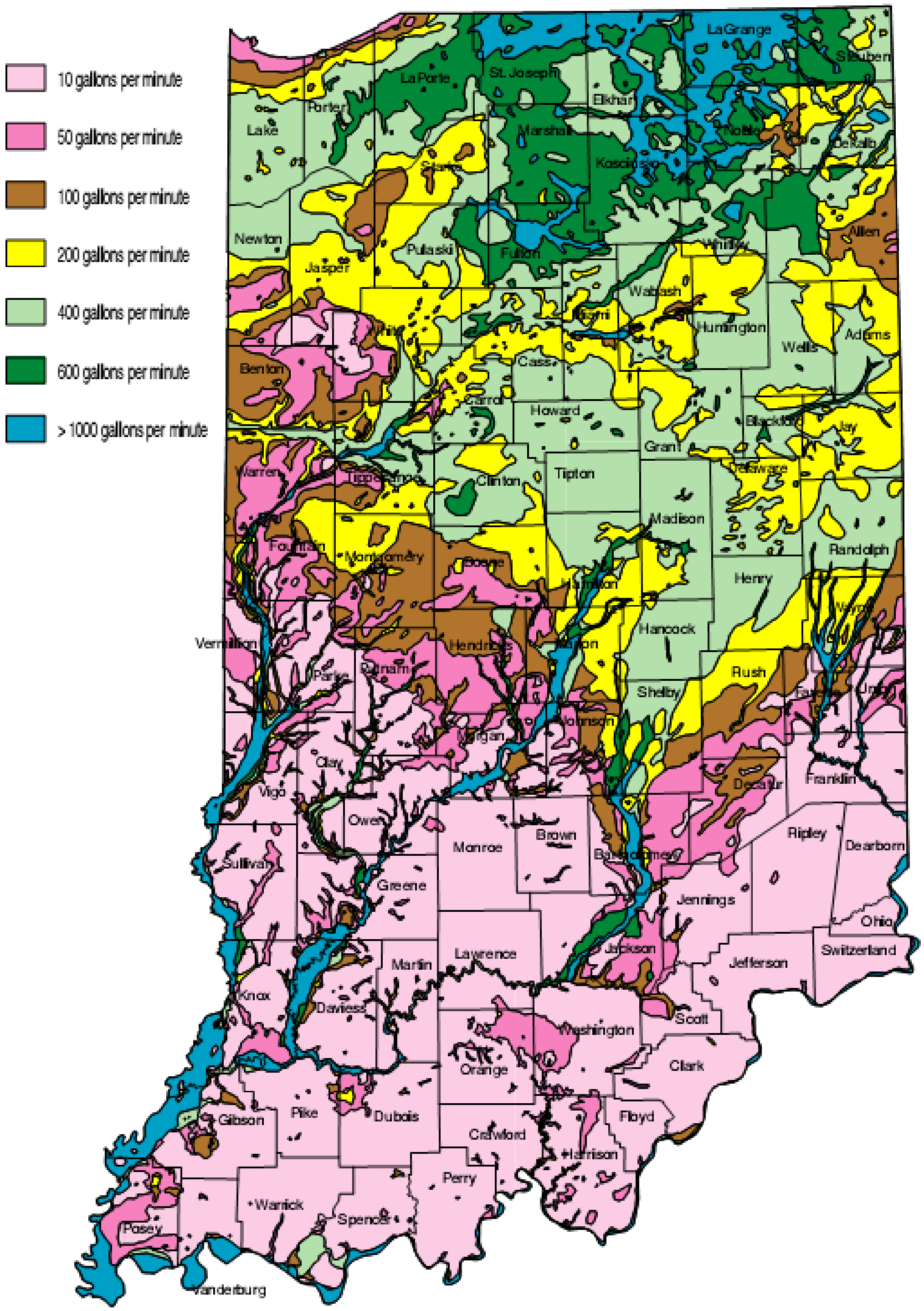


Figure X.4. Underground water mMap (Indiana Department of Natural Resources, Division of Water, 2007)

X.4.4 Water use summary

Both water from the Patoka River and underground water in the Francisco area are limited. Hence, SNG and hydrogen production are unlikely to be practical. If only FT liquids and power production are considered, and if the power export is proportional to the level reported by Van Bibber et al. (2007), the estimated water withdrawn from Patoka by a synfuel park at Francisco can be calculated. It is listed in Table X.7 and compared to the river's lowest average flow of 177 cfs. Even for a moderate sized plant (i.e., 20,000 bpd with about 100 MW power export), water use may be excessive during August through October. The water problem may be even worse when considering the possible lowest stream flow, as shown in Figure X.3, where flow could be as little as 25 cfs on dry days. The only viable alternative appears to be to pipe in water from Wabash River, about 20 miles to the west.

Table X.7. Estimated water withdrawn from Patoka River as a function of FT/power capacity vs. the lowest average stream flow in September (177 cfs = 2,723,574 bpd)

	10,000 bpd FT	**20,000 bpd FT**	**30,000 bpd FT**	**40,000 bpd FT**
Water withdrawn (10 bpd per FT bpd)	100,000	200,000	300,000	400,000
% water withdraw (10 bpd per FT bpd)	3.672	7.343	11.015	14.688
Water withdrawn (15 bpd per FT bpd)	150,000	300,000	450,000	600,000
% water withdraw (15 bpd per FT bpd)	5.508	11.016	16.524	22.032

X.5 Land/ real estate requirements

As shown in Figure X.2, there are empty surface mine sites in the area near the Francisco mine site. Other land is also available nearby. The area is relatively flat. If a large synfuel park/polygeneration plant, with a capacity of about 40,000 bpd plus about 100 MW of power export is built here, about 250 acres of land may be needed. It appears that this amount of land could be made available for a synfuel park. (A mine pool may be needed to allow for additional cooling of blow down water from the synfuel plant. The good news is that there are mine pools in the Francisco area, as shown in Figure X.2, which can be used as cooling ponds if they are needed.)

X.6 Transmission lines and power availability

A 345 kv AC power transmission line runs East-West just a few hundred feet south of the Francisco mining area. (See Figure X.1.) There is at least one substation connecting the transmission line and the township of Francisco, which would allow power use in the construction period. If power export from a potential synfuel park is significant, congestion of the transmission system in the region may occur. However, only a detailed connectivity study can determine how much power can be exported from the site.

X.7 Gas and oil pipelines

A gas pipeline owned by the Texas Gas Trans Corp. runs right through the Francisco mining area (See Figure X.1). Another gas pipeline owned by the Texas Eastern Trans Corp. also runs just a mile or so to the south of the mining area. These pipelines would allow the use of natural gas during the construction period, and could export SNG.

One crude oil pipeline and one refined petroleum product pipeline run through the mining area. It is possible that one of these lines could export FT diesel or naphtha from the park. Another option would be to piggyback pipelines on top of the existing ones for finished product export.

X.8 Labor force availability

A synfuel park at Francisco would likely not be able to draw all of its labor force from the local area. Additional personnel would need to be drawn from the surrounding communities of Princeton, Oakland, and Evansville.

X.9 Summary

In general, the Francisco site is a good candidate for developing a synfuel park. The primary advantage of this site is that coal transportation issues would be minimal. However, limited water availability may limit the scale of operations. The economical scale of operations is probably 20-40,000 tons per day of coal input, with outputs of 10-20,000 bpd of FT liquids and 50-100 MW of power export. Due to the limited availability of water, SNG or hydrogen production are not recommended.

XI. Fairbanks/Breed Power Station

The Fairbanks/Breed area is located a few miles east of the Wabash River. The site is the former location of the American Electric Power (AEP) Breed Power Station, which was demolished in 2007, leaving about 9,400 acres of unoccupied land. There are several candidate sites for a synfuel park on the site, including the two that are most promising:

a) The former location of the power station and
b) An alternative location, closer to Fairbanks but still near the rail line and the river.

According to Mr. Kent Curry, AEP's Director of Regulatory Affairs, the company has no intention of selling the land, nor do they have an immediate need to construct a new power plant there because Indiana & Michigan Power (I&M), a subsidiary of AEP, has sufficient capacity to serve its territory for the next few years. Figures XI.1–3 display the surrounding area; the topography; and the infrastructure, which includes transmission lines; pipelines for natural gas, oil, and refined petroleum products; highway and rail systems; and rivers and lakes.

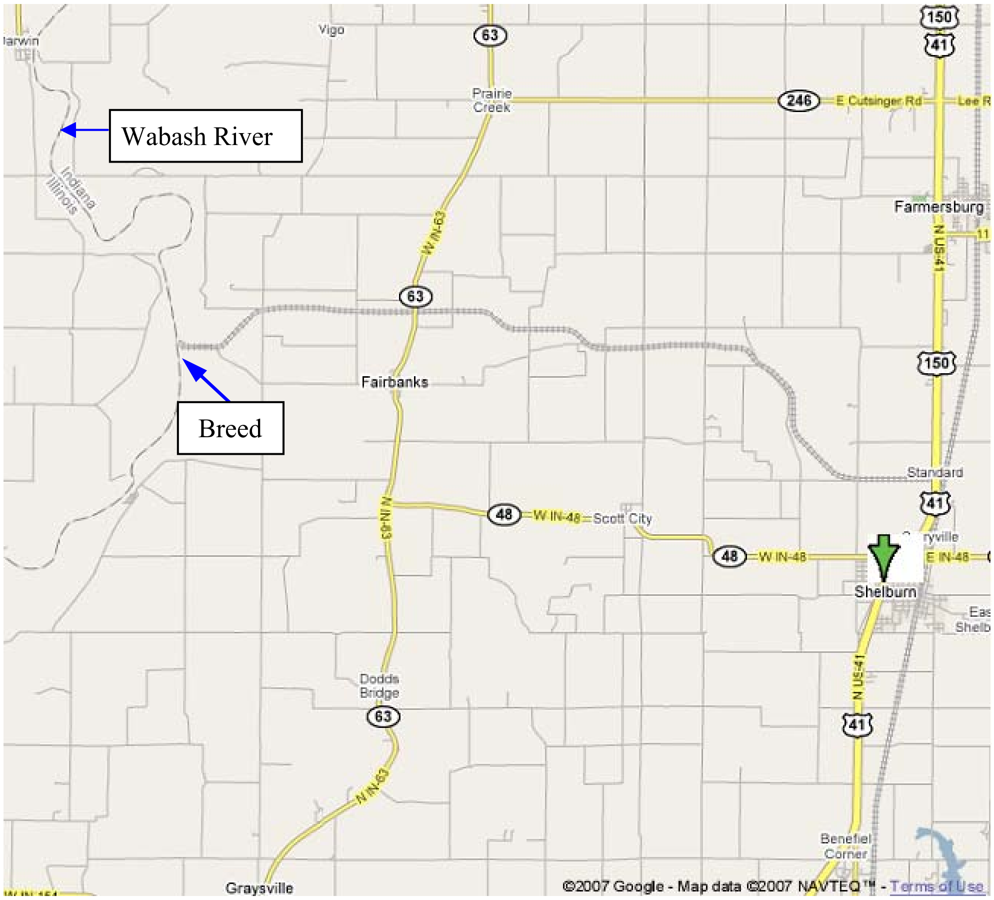


Figure XI.1. Map of the Breed/Fairbanks area (Google Maps, 2007)

Figure XI.2. Land topology of the Breed/Fairbanks area (Google Maps, 2007)

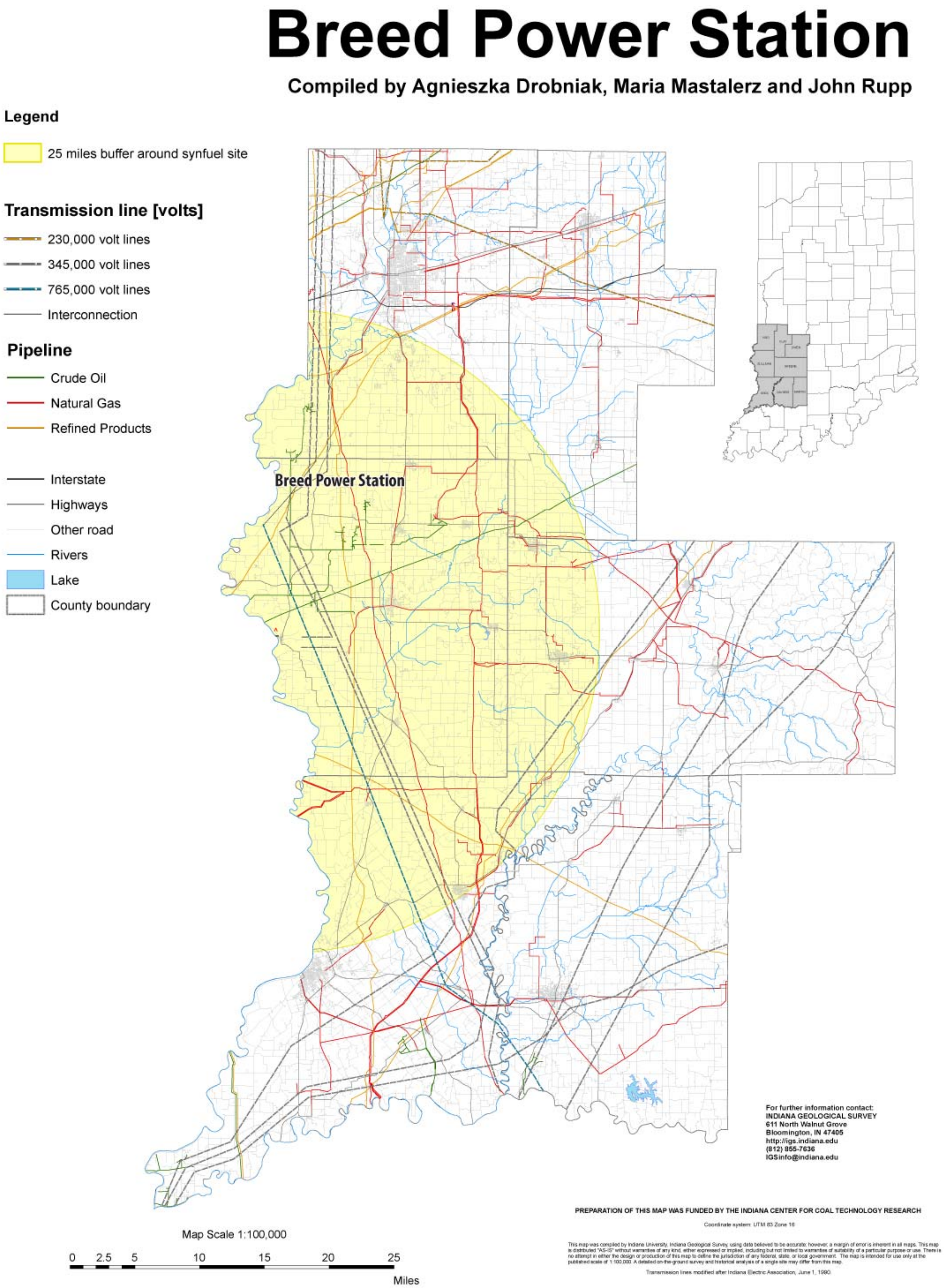


Figure XI.3. Infrastructure around the Breed Power Station

XI.1 Coal availability

There are no active coal mines in the immediate Breed/Fairbanks area. However, coal is available from mines 15-40 miles away. The Black Beauty Coal Company will soon open the Minnehaha mine, a surface mine south of Dugger about 25 miles from the site, which could supply coal via rail and/or truck. There are also some active mines nearby that could supply coal to a potential plant, including the Farmersburg # 1 South Pit in Vigo County, and the Kindill #3 Penndiana Pit in Sullivan County.

XI.2 CO_2 sequestration potential

There are four potential options for geological sequestration of CO_2 from a gasification facility at the Breed/Fairbanks site: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production, and injection into deep saline water-filled aquifers. Detailed results of the quantitative assessment are presented in sections A.2 of the appendix.

It appears that 498 million scf of enhanced coal bed methane could be produced with a potential storage of over 22 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 158 million standard barrels (stb) of crude oil and the potential to sequester 28 million tons of CO_2. Over 1.6 billion scf of enhanced shale gas could potentially be recovered with the flooding of about 619 million tons of CO_2. Injection into deep saline water-filled aquifers has the potential for the sequestration of another 16 billion tons. Thus, there are several potential options for geological sequestration of CO_2 in the Breed/Fairbanks area, with the greatest potential capacity in shale deposits and deep saline-filled aquifers.

XI.3 Transportation infrastructure/logistics

As discussed in IV, four processes require use of the transportation infrastructure: (1) shipment of large components of the synfuel park, (2) transportation of coal, (3) distribution of finished products and (4) transportation of slag/ash. The rail lines that serviced the power plant at Breed are currently inactive, but could probably be brought back into service at a reasonable cost. We focus on this aspect of the transportation system in the analysis of the adequacy of the infrastructure at the Breed/Fairbanks site.

XI.3.1 Shipment of large pieces of equipment to Fairbanks/Breed

Due to weight and size limits, it is impossible to transport very large pieces of equipment to the Breed/Fairbanks area on the interstate highway system. Therefore, we consider only the rail system for transporting very large equipment. As shown in Table XI.1, there are about 16 overpasses and bridges between Evansville and Sullivan, but there are no additional overpasses from Sullivan to Breed/Fairbanks on the rail line connected near Shelburn (Figure XI.4). The clearance under these overpasses will limit the size of large equipment that can be delivered. These limitations on the size of the equipment that can be delivered to the Breed/Fairbanks site may result in more extensive use of land. Because of economies of scale in the production efficiency, particularly of FT reactors, this limitation may also adversely affect the economics of the plant.

Table XI.1. Overpasses and bridges from Evansville to Minnehaha/Fairbanks (Appendix B)

#	Intersection with roads or rivers	Location
1	West Lloyd Expy	Evansville
2	West Delaware St.	Evansville
3	IN-66	North of Evansville
4	Darmstadt Rd	North of Evansville
5	Old State Rd	North of Evansville
6	I-64	South of Haubstadt
7	US-41	South of Princeton
8	US-41 Parallel	South of Princeton
9	W Brumfield Ave	Princeton
10	Bridge 6	South of Patoka
11	Bridge 8	South of Decker
12	US-41	South Vincennes
13	US-50	North of Vincennes
14	Old US-41	South of Oaktown
15	US-41	North of Oaktown
16	US-150	North of Oaktown

Figure XI.4. Connection of rail line to Breed and Fairbanks area (Google Maps, 2007)

XI.3.2 Transportation of coal to Fairbanks/Breed

As indicated in the section on coal availability, if a synfuel park is built near Breed/Fairbanks, coal can be transported from several sources via rail. The scale of operations may be limited by congestion of the rail system.

XI.3.3 Transportation of finished products from Fairbanks/Breed

Primary finished products of a synfuel park are likely to be FT liquids, SNG, hydrogen, electric power and sulfur. Except for SNG and power, other products can be shipped via rail and/or trucks. The Fairbanks area is connected to the CSX rail systems, which may allow large quantities of product shipment, depending on congestion. State highways can also be used for small quantities.

XI.3.4 Transportation of slag/ash from Fairbanks/Breed

Slag/ash can be trucked to a nearby location. The topography in the Breed/Fairbanks area includes some hilly areas, which may be good for solid waste disposal. Slag/ash can also be deposited in mined-out sections of coal mines in the area. This may be an economical way of disposal because rail cars and/or trucks can haul coal to the synfuel plant and backhaul slag/ash to the mines.

XI.4 Water requirements and resources

The primary practical source of water at the Breed/Fairbanks site is the Wabash River, which is about a mile to the west of Fairbanks (see Figures XI.1 and XI.2). The historical stream flow at Terre Haute (the closest monitoring station) of the Wabash is shown in Table XI.2.

The minimum stream flow near Fairbanks is estimated by weighting the minimum flow data recorded at Terre Haute and Riverton (as reported by the U.S. Department of the Interior, U.S. Geological Survey, 2006) over the past 10 years. The lowest minimum over the past 10 years is about 1235.6 cfs (Figure XI.5), estimated for the Wabash River near Fairbanks, and the equivalent of this lowest minimum daily flow is then 19,012,707 bpd. (The monthly average stream flow is much higher. See Figure XI.6.)

For this worst case scenario, the water withdrawn by a synfuel park is listed in Table XI.3. This table shows that even under the worst scenario of water flow rate, the synfuel park would not withdraw more than 4% of water from the Wabash River near Fairbanks for a plant of 50,000 bpd with co-production of power. If SNG production is also included as listed in Table XI.4, water withdrawal will be greater, but it can still be supported by the river. Regulations on water use and discharge are the same as that for the Francisco area. (See Section X.4.) In fact, the average flow rate estimated for the section of Wabash River near Fairbanks is much greater than the minimum, as shown in Figure XI.6.

Table XI.2 Average Wabash stream flow near Terre Haute (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	**Mean of daily mean values for each day for 79 years of record, in,cfs (Calculation Period 1927-10-01 -> 2006-09-30)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	13,700	15,200	18,000	18,700	16,700	12,900	9,790	6,110	4,690	4,860	4,340	8,870
2	14,100	15,200	17,600	18,800	16,700	12,500	9,460	6,230	4,990	5,140	4,640	8,980
3	14,000	15,200	17,100	18,600	16,600	12,200	9,290	6,280	5,230	5,000	5,130	9,320
4	14,500	14,800	17,000	18,800	16,000	11,700	9,470	6,340	5,230	4,830	5,500	9,620
5	15,200	14,900	17,400	18,800	15,500	11,200	9,730	6,340	4,920	4,690	5,760	9,460
6	15,600	14,500	17,600	19,000	15,100	10,900	10,100	6,300	4,640	4,590	5,960	9,350
7	15,700	14,200	17,800	19,000	14,800	11,000	10,000	6,100	4,300	4,460	6,030	9,270
8	15,500	13,800	17,900	19,000	14,800	11,100	9,480	5,790	3,920	4,540	5,960	9,560
9	15,200	13,600	18,100	19,000	14,500	11,500	9,020	5,390	3,960	4,540	5,730	9,830
10	14,700	13,900	18,300	18,900	13,900	11,600	9,060	5,090	3,880	4,730	5,560	9,930
11	14,100	14,100	18,000	18,900	14,100	11,500	9,240	4,860	3,760	4,740	5,600	9,990
12	13,500	14,200	18,000	19,100	14,800	12,100	9,310	4,880	3,660	4,830	5,760	10,300
13	13,200	14,500	18,300	19,400	15,600	13,000	9,050	4,950	**3,610**	5,240	6,100	10,400
14	13,200	14,800	18,800	19,800	16,400	13,800	9,140	4,720	3,800	5,510	6,560	10,300
15	13,600	15,000	19,100	20,200	17,000	14,700	9,150	4,690	4,370	5,470	6,970	10,400
16	13,800	15,100	19,500	20,200	17,200	15,200	9,020	4,720	4,530	5,300	7,100	10,500
17	13,400	15,600	19,800	19,900	17,000	15,100	8,610	4,800	4,450	5,220	7,410	10,800
18	13,200	15,800	19,700	19,500	17,400	14,500	8,330	4,970	4,260	5,190	7,570	11,000
19	13,500	16,100	19,600	19,000	17,900	13,800	8,340	5,030	4,010	5,200	7,840	11,000
20	13,600	16,600	19,500	18,700	18,300	13,200	8,430	5,310	3,870	5,170	8,110	10,700
21	13,900	16,900	19,700	18,400	17,900	12,600	8,290	5,390	3,920	5,060	8,330	10,500
22	14,300	17,200	19,800	18,500	17,000	12,300	7,990	5,050	3,990	4,950	8,120	10,700
23	14,500	17,700	19,500	18,500	15,900	12,100	7,540	4,630	4,140	4,830	8,030	10,600
24	14,600	17,900	19,100	18,400	15,300	11,600	7,470	4,590	4,160	4,860	7,950	10,600
25	14,300	18,100	18,700	18,200	14,800	11,200	7,350	4,330	4,060	4,940	7,900	10,700
26	14,300	18,500	18,400	18,000	14,500	10,700	7,210	4,090	3,990	4,890	8,070	10,900
27	14,200	18,100	18,400	17,700	14,500	10,500	7,190	3,930	3,970	4,860	8,190	11,000
28	14,000	18,000	18,600	17,300	14,400	10,600	7,100	3,860	4,180	4,810	8,510	11,100
29	13,900	16,500	18,300	17,200	14,000	10,600	6,870	4,090	4,390	4,740	8,640	11,300
30	14,300		18,100	16,900	13,700	10,300	6,350	4,220	4,660	4,590	8,710	12,000
31	14,900		18,200		13,500		6,090	4,480		4,450		12,900

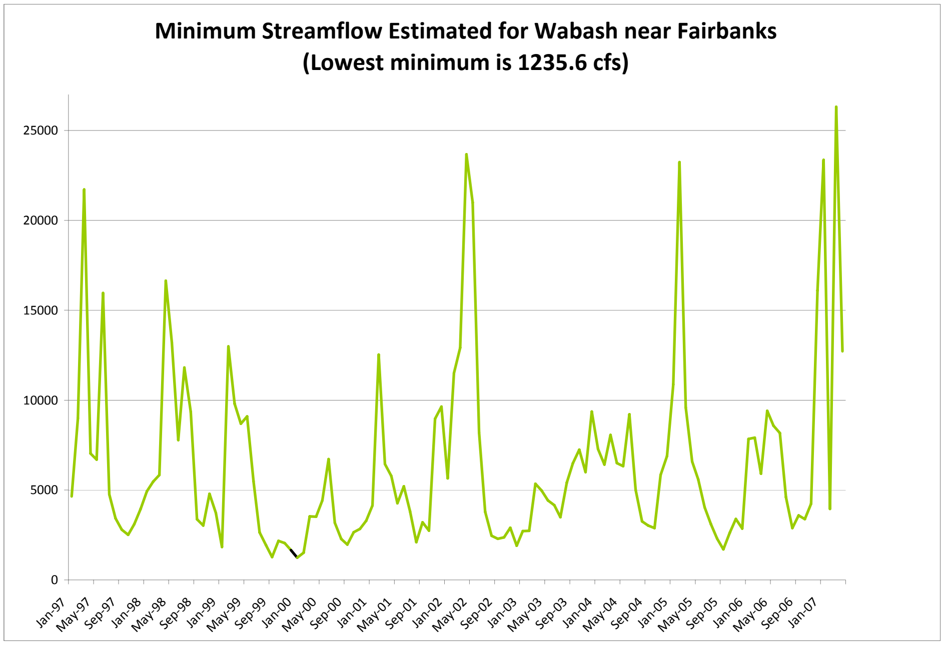


Figure XI.5. Monthly minimum stream flow estimated for Wabash near Breed/Fairbanks for the last 10 years (Source: Appendix C)

Table XI.3. Estimated water withdrawn from the Wabash River near Fairbanks as a function of FT/power capacity without SNG (vs. the minimum stream flow over the past 10 years)

	10,000 bpd FT	**20,000 bpd FT**	**30,000 bpd FT**	**40,000 bpd FT**	**50,000 bpd FT**
Water withdrawn (10 bpd per FT bpd)	100,000	200,000	300,000	400,000	400,000
% water withdrawn (10 bpd per FT bpd)	0.526	1.052	1.578	2.104	2.630
Water withdrawn (15 bpd per FT bpd)	150,000	300,000	450,000	600,000	750,000
% water withdrawn (15 bpd per FT bpd)	0.789	1.578	2.367	3.156	3.945

Table XI.4. Estimated water withdrawn from the Wabash River near Fairbanks as a function of SNG capacity (vs. the minimum stream flow over the pPast 10 years)

	50,000 MMBtu/day	100,000 MMBtu/day
Water withdrawn bbl (2.766 bbl per MMBtu)	138,300	276,600
% water withdrawn	0.72	1.44
Water withdrawn bbl (4.14 bbl/MMBtu)	207,450	414,900
% water withdrawn	1.08	2.16

Notes: One bbl FT has an energy content around 4.7 MMBtu, which is obtained in the following manner: diesel/bbl = 5.4 MMBtu, naphtha/bbl = 3.7 MMBtu, assuming a 60% diesel and 40% naphtha in the FT product mix. If SNG consumes 30% more water than the FT in equivalent basis (MMBtu), the water consumption for SNG production is estimated to be 2.766 bbl of water per MMBtu. The alternative water withdrawal rate of 4.14 bbl/MMBtu is based on a 50 percent increase in the water requirements.

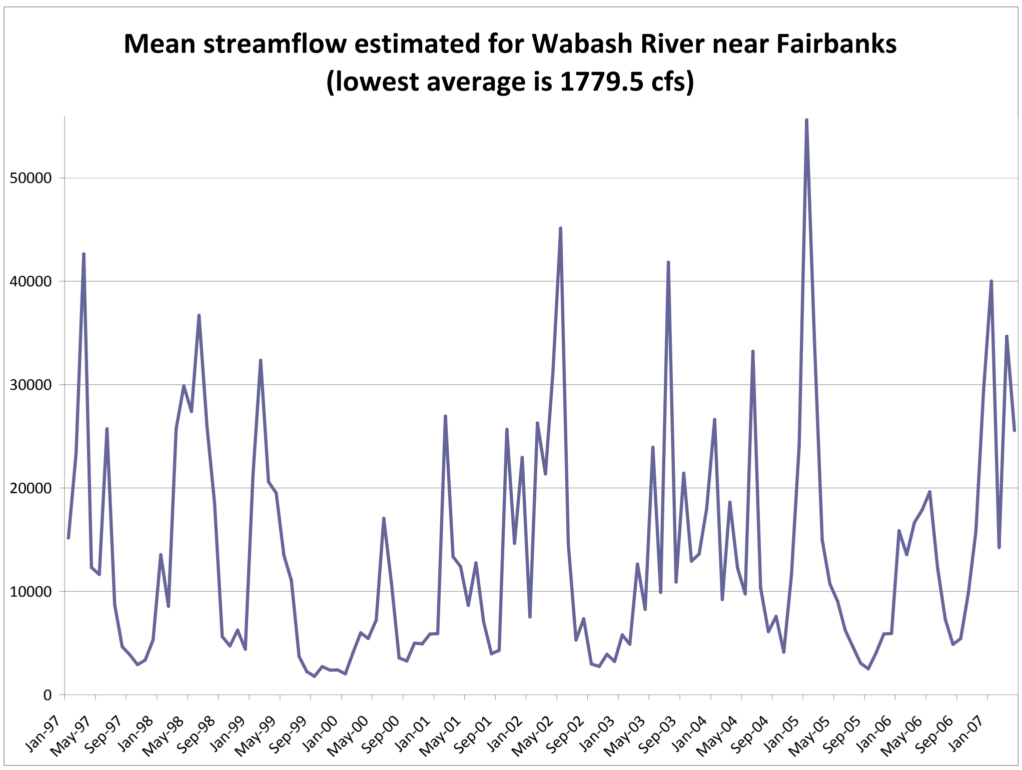


Figure XI.6. Average stream flow estimate for Wabash near Fairbanks (Appendix C)

XI.5 Land/real estate requirements

Breed/Fairbanks is a brownfield site with 9,400 acres of currently unoccupied land. This amount of land should be sufficient to support a synfuel park with a capacity equivalent to 40,000 bpd FT liquids with power export and/or SNG production. Both the plant and its ancillary facilities (for coal storage, cooling pond, and finished products storage, as well as land fill for slag/ash) should be able to be accommodated onsite.

XI.6 Transmission lines and power availability

Power transmission line connections exist at the Breed power station. The old power station is connected to the grid via 765 KV lines. Other lines are also available in the area (see Figure XI.3), and a substation is maintained at Breed. Thus, transmission capacity is available to supply power during the construction phase and for export during the operation phase.

XI.7 Gas and oil pipelines

A natural gas pipeline owned by the Midwestern Gas Transmission Corp. is located 4-5 miles to the east of the site (see Figure XI.3). There is a pipeline for refined products about 2 miles to the east. Connecting pipelines of appropriate capacity may be needed to link the plant to the major pipeline system.

XI.8 Labor force availability

Terre Haute, Sullivan, and Vincennes are not far from the Breed/Fairbanks site. Unskilled personnel to operate the plant may be sourced from these areas. Skilled personnel may be drawn from a wider area.

XI.9 Summary

The Breed/Fairbanks site appears to be favorable for development of a synfuel park. Adequate land, water and infrastructure are either available or could be developed at reasonable cost. Estimated capacity that could be supported is on the order of 100,000 tons of coal per day. Products could include a mix of FT liquids, exported power, and SNG.

XII. Merom

The Merom site is near the Wabash River, about 10 miles west of Sullivan. The Merom power station is owned and operated by Hoosier Energy and has a capacity of 1,080 MW. Turtle Creek Lake, with a surface area of about 1,550 acres, provides cooling water to the power plant. Groundwater is also used for steam generation. Excess land is available on site and is being held by the company in anticipation of eventual capacity additions. Mr. Mike Rampley, Senior Vice President of Hoosier Energy, has expressed the view that the company would like to see a synfuel park developed in the region near the Merom power station. Hoosier Energy may be interested in a small ownership stake in the project, and may provide power and some other assistance to the development as needed. Highways, roads, and rail lines, as well as the topography and supporting infrastructure are displayed in Figures XII.1-XII.3.

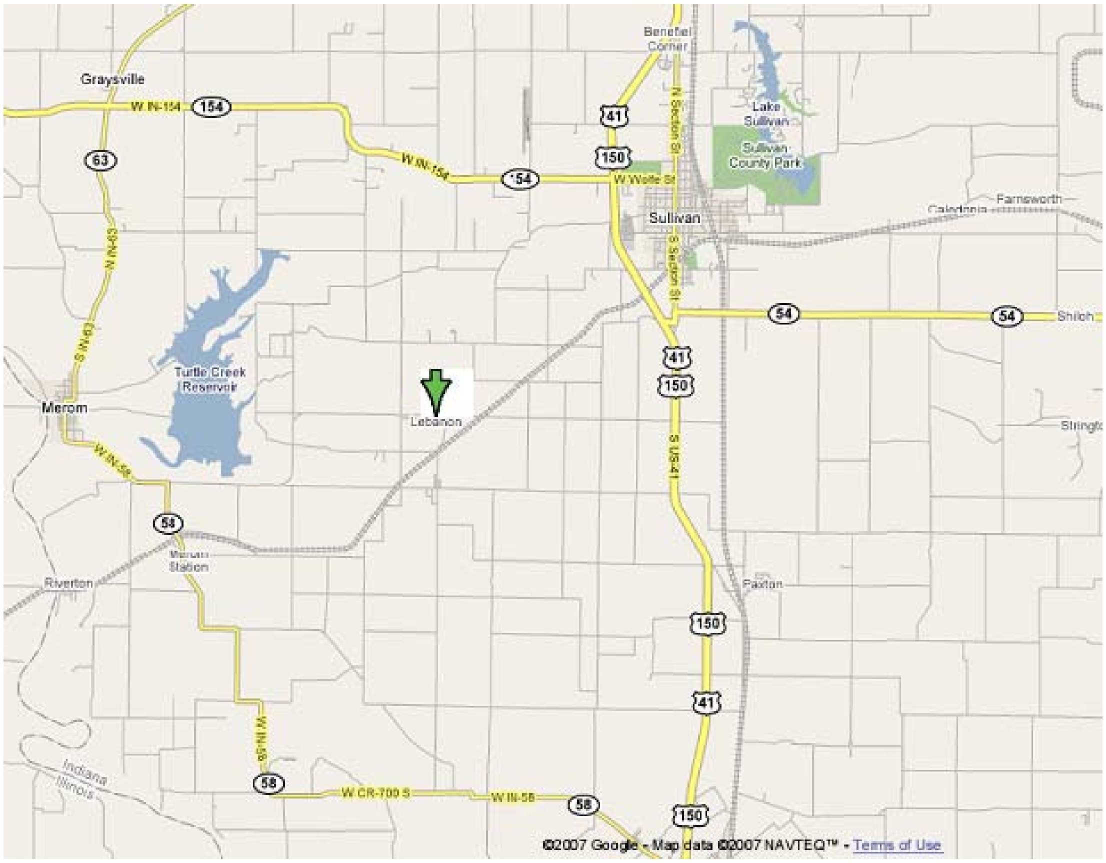


Figure XII.1. Map of the Merom region (Google Maps, 2007)

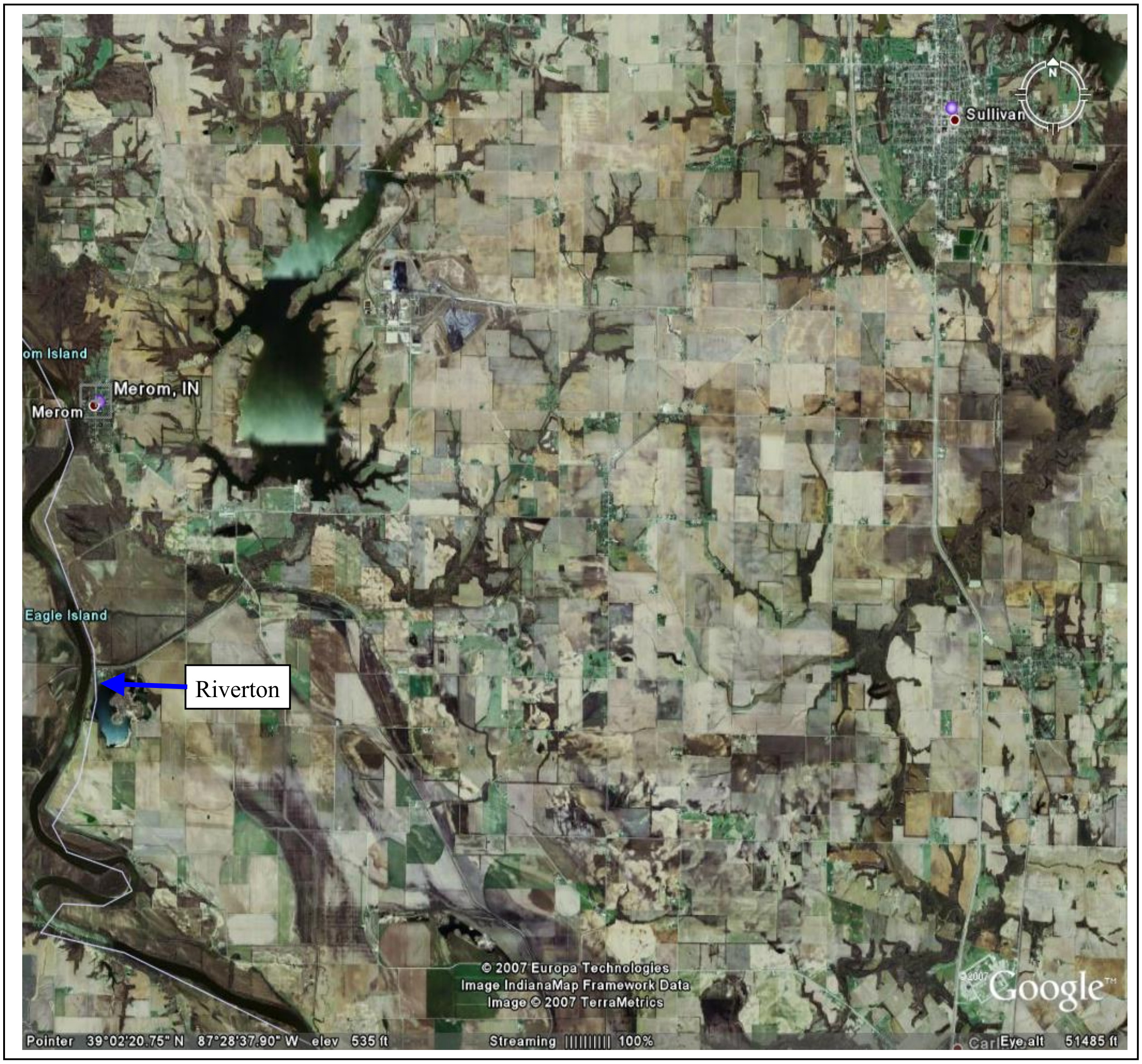


Figure XII.2. Land topography of the Merom/Sullivan region (Google Maps, 2007)

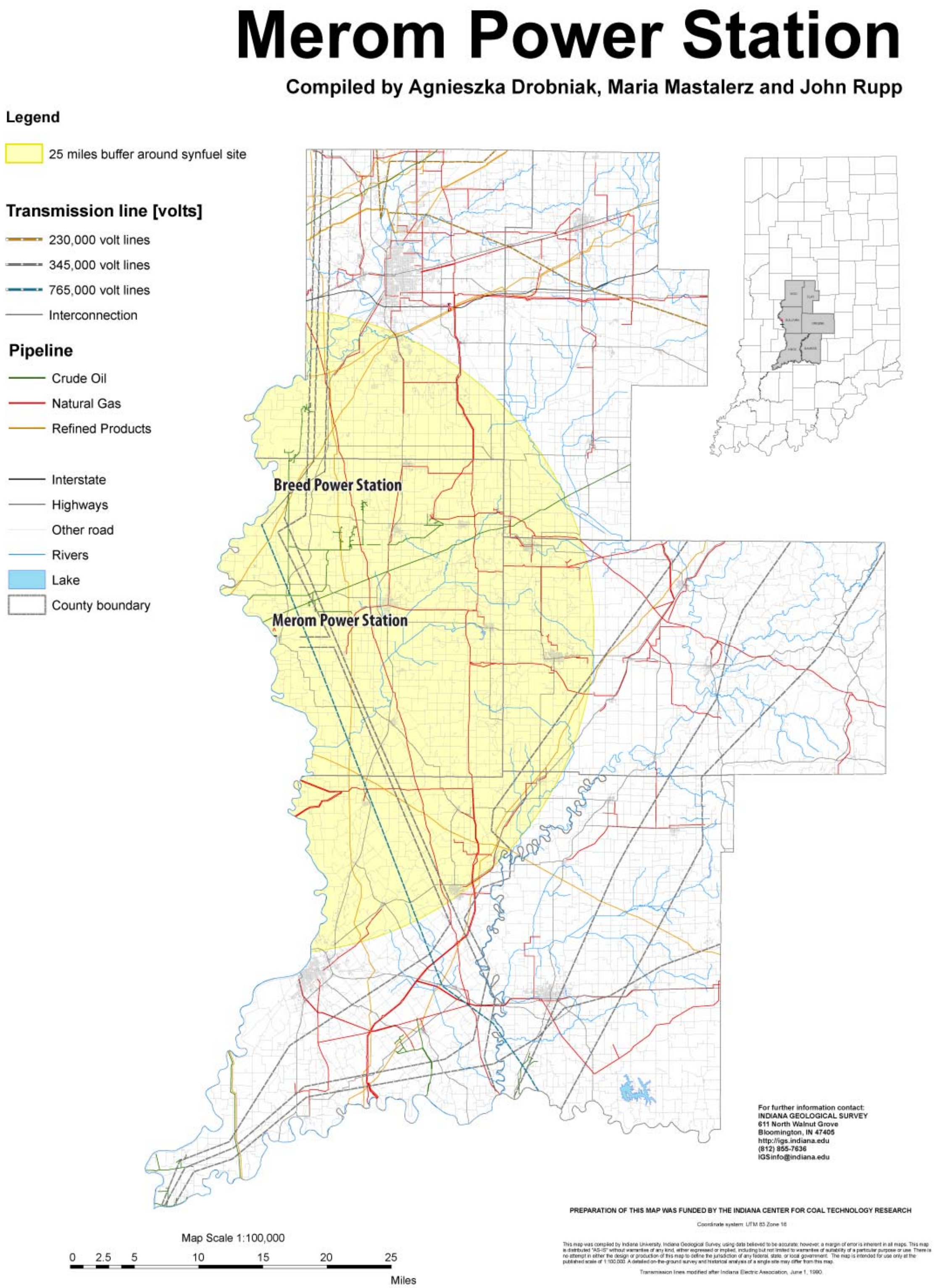


Figure XII.3. Infrastructure of the Merom area

XII.1 Coal availability

There is no coal production within 15 miles of Merom. However, the Kindill #3 Penndiana Pit is about 15 miles away, south of the town of Dugger in Sullivan County. The Black Beauty Coal Corp. is expected to reopen the Minnehaha mine, a surface mine about three miles south of Dugger, which could provide coal to a potential synfuel park in the Merom area. Coal from these mines can be shipped to the Merom site via rail or truck. In addition, some mines further from Merom can also supply coal to the potential plant, including the Farmersburg # 1 South Pit in Vigo County.

XII.2 CO_2 sequestration potential

There are four potential options for geological sequestration of CO_2 from a gasification facility at the Merom site: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production and injection into deep saline water-filled aquifers. Detailed results of the quantitative assessment are presented in sections A.2 of the appendix.

It appears that 498 million scf of enhanced coal bed methane could be produced with a potential storage of over 22 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 158 million standard barrels (stb) of crude oil and the potential to sequester 28 million tons of CO_2. Over 1.6 billion scf of enhanced shale gas could potentially be recovered with the flooding of about 619 million tons of CO_2. Injection into deep saline water-filled aquifers has the potential for the sequestration of another 16 billion tons. Thus, there are several potential options for geological sequestration of CO_2 in the Merom area, with the greatest potential capacity in shale deposits and deep saline-filled aquifers.

XII.3 Transportation infrastructure/logistics

As discussed in section IV, the transportation infrastructure will be needed for: (1) shipment of large components of the synfuel park during the construction phase and (2) transportation of coal, (3) distribution of finished products and (4) transportation of slag/ash during the production phase. Rail lines service the power plant at Merom and thus a site close by would have ready access to rail transportation, although an analysis of the potential effects of congestion should be performed. Highways are also within about 10 miles, making transport of moderate quantities by truck practical.

XII.3.1 Shipment of large pieces of equipment to Merom

Due to weight and size limits, it is impractical to transport very large equipment to the Merom area on the highway system. Hence, we only consider using the rail system for this purpose. Large equipment destined for the Merom area will most likely be delivered by barge to either Evansville or Jeffersonville. As shown in Table XII.1, there are about 16 overpasses and bridges from Evansville to Sullivan, but there are no additional overpasses from Sullivan to Merom. The clearance under these overpasses will limit the size of large equipment that can be delivered to Merom by rail. Large facilities can also be delivered by barge to Jeffersonville and then shipped via rail to the Merom area. There are 13 overpasses along that route, as shown in Table XII.2. It will be essential to coordinate with the equipment suppliers and the railroad to determine the feasibility and economics of delivery. Limitations on the size of large equipment may have an impact on the economic efficiency of the synfuel park. This is particularly true of FT reactors whose conversion efficiency exhibits substantial economies of scale.

Table XII.1. Overpasses and bridges from Evansville to Sullivan (Source: Appendix B)

	#	**Intersection with roads or rivers**	**Location**
From Evansville to Sullivan	1	West Lloyd Expy	Evansville
	2	West Delaware St.	Evansville
	3	IN-66	North of Evansville
	4	Darmstadt Rd	North of Evansville
	5	Old State Rd	North of Evansville
	6	I-64	South of Haubstadt
	7	US-41	South of Princeton
	8	US-41 Parallel	South of Princeton
	9	W Brumfield Ave	Princeton
	10	Bridge 6	South of Patoka
	11	Bridge 8	South of Decker
	12	US-41	South Vincennes
	13	US-50	North of Vincennes
	14	Old US-41	South of Oaktown
	15	US-41	North of Oaktown
	16	US-150	North of Oaktown

Table XII.2. Overpasses from Jeffersonville to Sullivan via Bedford (Appendix B).

	#	**Intersection with roads or rivers**	**Location**
From Jeffersonville to Crane	1	IN-62	North New Albany
	2	I-265	North New Albany
	3	W IN-56	Salem
	4	IN-450	Bedford
	5	IN-37	West Bedford
	6	IN-37 parallel	West Bedford
	7	IN-450	West of Bedford
	8	Farm Bridge	East of Crane
	9	A tunnel	Crane
	10	IN-45	Crane
From Crane to Sullivan	11	A bridge	North of Elnora
	12	IN-54	Dugger
	13	N Cr-525 E	East of Sullivan

XII.3.2 Transportation of coal to Merom

As indicated in the section on coal availability (XII.1), if a synfuel park is built near Merom coal can be transported from a number of nearby mines via rail. The scale of operations may be limited by congestion of the rail system.

XII.3.3 Transportation of finished products from Merom

Primary finished products of a synfuel park are likely to be FT liquids, SNG, hydrogen, electric power and sulfur. Except for SNG and power, other products can be shipped via rail and/or trucks. The Merom area is connected to the rail network via the CSX rail systems, which may allow large quantities of product shipment, depending on congestion of the network. State highways can also be used for small quantities of product shipment.

XII.3.4 Transportation of slag/ash from Merom

Slag/ash can be disposed onsite. This has been the practice at the Merom power station, where about 290 acres of land have been used for gypsum/ash disposal. Slag/ash can also be trucked to nearby locations for disposal, such as mined out strip mines near Sullivan. Such areas are abundant and scattered near the Minnehaha area as shown in Figure XII.2.

XII.4 Water requirements and resources

XII.4.1 Water resources from the Wabash River

The primary water resource for a synfuel park in the Merom area is the Wabash River which is located 1-2 miles west of the Merom power station, as shown in Figures XII.1 and XII.2. In addition, there appears to be sufficient ground water for purposes such as steam generation. There is no monitoring station near Merom, and the average stream flow near Riverton is listed in Table XII.3 as a proxy. The proxy is a good representation of the actual stream flow near Merom because the two locations are very close – Riverton is just a mile or so from the Merom power station, by the rail line at the river edge. Table XII.3 shows that even in the driest month of September, the lowest average stream flow is still 4,300 cfs, which is equivalent to 66,165,943 bpd.

The minimum daily average stream flow near Merom over the past 10 years is about 1,955 cfs, as reported by the USGS (Figure XII.4 and Appendix C). This is equivalent to about 30,077,807 bpd, about half of the monthly average amount converted to a bpd basis. Even for this minimal level of flow, the water withdrawn by a synfuel park without SNG production is no more than a few percent of the stream flow (Table XII.4). This percentage is even further reduced if ground water is also used for steam generation. If SNG co-production is included, water requirements will be greater. However given that a doubling of water withdrawals would amount to less than 5% of the minimum stream flow over the past 10 years, it appears that including some SNG in the output mix of the synfuel park should be feasible.

Table XII.3. Average Wabash stream flow at Riverton near Merom (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	**Mean of daily mean values for each day for 67 years of record, in cfs (Calculation Period 1939-10-01 -> 2006-09-30) Calculation period restricted by USGS staff due to special conditions at/near site**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	14,400	16,200	19,500	20,800	19,700	15,600	11,500	7,490	5,280	4,940	5,140	9,670
2	14,800	16,900	19,400	20,600	19,500	15,500	11,000	7,300	5,650	5,020	5,290	9,650
3	15,200	17,200	19,200	20,500	19,000	15,200	10,400	7,350	5,730	5,050	5,490	9,860
4	15,800	17,300	19,300	20,700	18,200	14,600	10,100	7,280	5,740	4,990	5,530	10,200
5	16,300	17,300	19,500	20,800	17,700	13,800	9,980	7,410	5,660	5,090	5,680	10,100
6	16,300	17,300	19,500	20,700	17,100	13,100	9,910	7,480	5,500	5,060	5,780	9,900
7	16,300	17,000	19,300	20,600	16,700	12,500	10,100	7,430	5,290	4,960	5,930	9,810
8	16,300	16,400	19,300	20,600	16,800	12,300	9,870	7,130	4,950	4,900	5,960	9,900
9	16,100	15,800	19,700	20,500	16,500	12,400	9,650	6,690	4,790	4,860	5,870	10,000
10	15,800	15,600	20,300	20,400	16,000	12,900	9,620	6,240	4,740	5,020	5,840	10,000
11	15,400	15,600	20,700	20,500	15,800	13,200	9,820	5,920	4,550	5,100	5,880	10,100
12	14,700	15,400	21,000	20,700	15,700	13,500	10,200	5,590	4,410	5,130	5,940	10,300
13	13,900	15,400	20,700	20,800	16,200	13,900	10,100	5,550	4,410	5,240	6,130	10,500
14	13,200	15,500	20,500	20,700	16,700	14,200	9,990	5,530	**4,300**	5,450	6,610	10,900
15	12,800	15,800	20,600	20,900	17,200	14,900	10,200	5,310	4,460	5,550	7,180	11,200
16	12,800	16,100	20,700	21,400	17,600	15,700	10,500	5,380	4,730	5,500	7,680	11,300
17	12,800	16,400	21,000	22,000	18,000	16,200	10,400	5,340	4,900	5,460	8,060	11,500
18	12,900	16,700	21,200	22,400	18,400	16,700	10,200	5,370	4,900	5,550	8,460	11,600
19	13,100	17,000	21,500	22,200	18,500	16,500	9,890	5,340	4,730	5,610	8,810	11,600
20	13,000	17,500	21,800	21,800	19,300	16,500	9,730	5,440	4,540	5,550	9,170	11,400
21	13,000	18,100	22,100	21,200	20,100	16,000	9,740	5,730	4,420	5,570	9,460	11,200
22	13,400	18,900	21,800	20,600	20,000	15,400	9,640	5,690	4,480	5,580	9,450	11,200
23	13,900	19,500	21,400	20,300	19,400	15,000	9,340	5,390	4,560	5,570	9,330	11,400
24	14,200	19,700	21,200	20,200	18,700	14,300	8,900	5,200	4,610	5,610	9,220	11,600
25	14,300	19,700	21,100	20,100	18,000	13,500	8,820	5,130	4,660	5,650	9,110	11,900
26	14,500	19,600	21,000	19,900	17,400	13,000	8,660	4,900	4,730	5,640	9,220	12,200
27	14,800	19,800	21,000	19,700	17,100	12,700	8,590	4,670	4,710	5,530	9,440	12,200
28	14,700	19,700	21,000	19,600	16,900	12,500	8,620	4,480	4,680	5,410	9,810	12,300
29	14,800	14,700	21,000	19,600	16,300	12,400	8,450	4,610	4,790	5,320	9,800	12,600
30	15,300		21,000	19,500	15,700	12,000	8,080	4,830	4,880	5,230	9,720	13,100
31	15,700		21,000		15,700		7,780	4,870		5,140		13,700

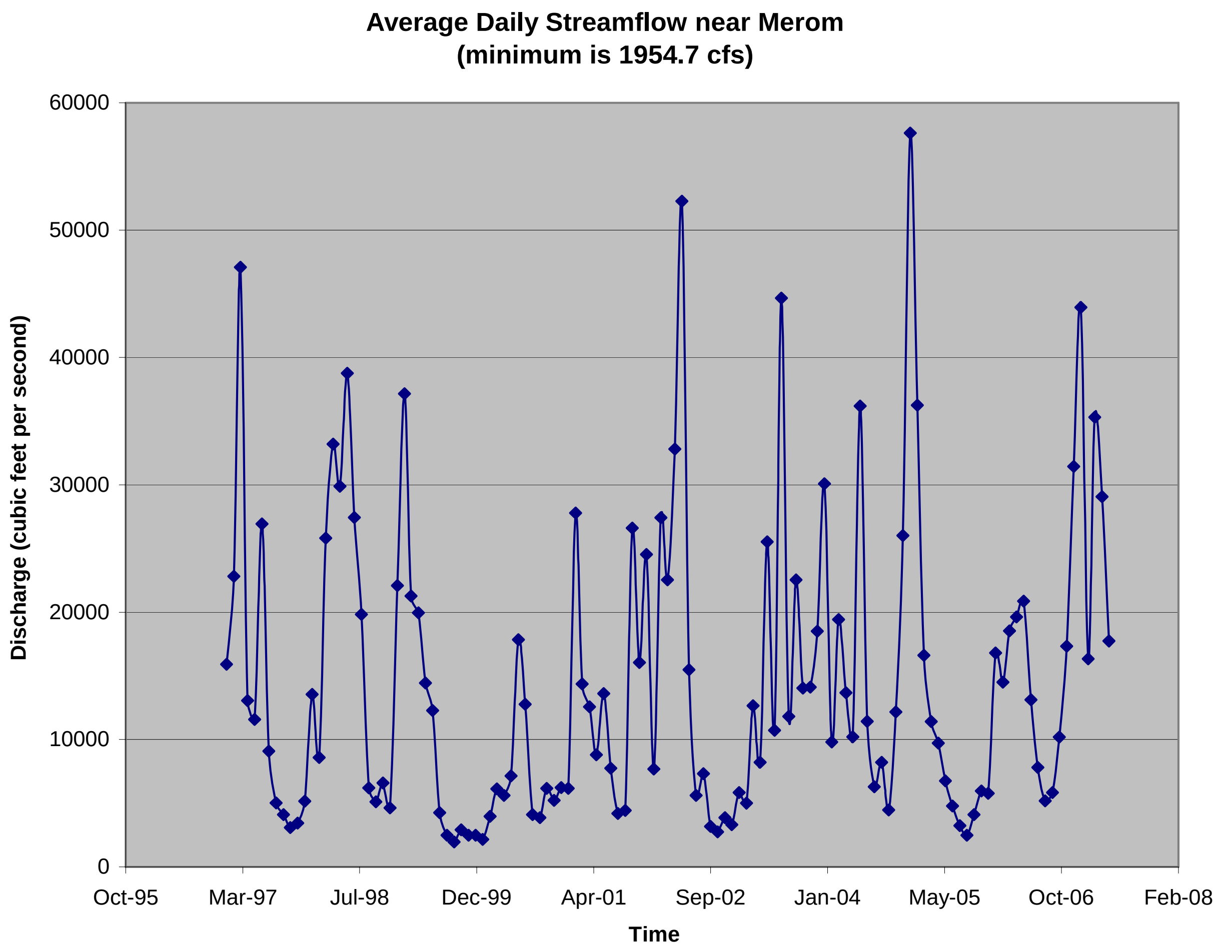


Figure XII.4. Average Wabash stream flow at Riverton near Merom for the past 10 years (Source: Appendix C)

Table XII.4. Estimated water withdrawn from the Wabash River near Fairbanks as a function of FT/power capacity (vs. the Minimum Stream Flow over the past 10 years)

	10,000 bpd FT	**20,000 bpd FT**	**30,000 bpd FT**	**40,000 bpd FT**	**50,000 bpd FT**
Water withdrawn (10 bpd per FT bpd)	100,000	200,000	300,000	400,000	400,000
% water withdrawn (10 bpd per FT bpd)	0.332	0.665	0.997	1.33	1.662
Water withdrawn (15 bpd per FT bpd)	150,000	300,000	450,000	600,000	750,000
% water withdrawn (15 bpd per FT bpd)	0.498	0.997	1.496	1.995	2.493

XII.4.2 Underground water resources

Merom is near the Wabash River, in Sullivan County (see Figure XII.2), and underground water is plentiful in the area. As indicated earlier, the Merom power station has been using Turtle Creek Lake for primary cooling and underground water for steam generation. It is unlikely that the Turtle Creek Lake can provide sufficient capacity for cooling a large synfuel park. Therefore, the synfuel park, if built in Merom, will have to depend on the river and underground water for cooling and steam generation.

XII.4.3 Water use regulation

According to the Division of Water of the Indiana Department of Natural Resources (DNR), there are no restrictions on water withdrawal from the Wabash River, except that the withdrawal must be registered with the DNR if it exceeds 100,000 gallons per day (Appendix C). The DNR also requires that it be notified of the amount of water withdrawn per year.

XII.4.4 Water use summary

Water from the Wabash and underground water in the Merom area are both reasonably abundant. Hence, a fairly large synfuel park, on the order of 100,000 tons of coal input per day, is potentially sustainable. In addition, water resources are sufficient to consider including SNG and hydrogen in the park's product mix.

XII.5 Land/real estate requirements

As shown in Figure XII.2, there is substantial agricultural land in the Merom area. A large synfuel park in the Merom area with capacity to process about 100,000 tons of coal per day will require on the order of 300-350 acres of land. This land would need to be acquired.

XII.6 Transmission lines and power availability

Existing power transmission lines connecting the Merom power station to the grid will allow the use of power for construction. However, the transmission capacity of the Merom station may not be able to accommodate a large power export from the synfuel park to the grid. Hence, a substation and a few miles of transmission lines will likely need to be built for significant power export. New transmission lines can be either connected to the Breed substation a few miles to the north or to one of the substations in Terre Haute, about 12 miles to the north.

XII.7 Gas and oil pipelines

Merom does not have a direct connection to a gas pipeline, nor an oil pipeline. However, Hoosier Energy (HE) owns right of way to build a gas pipeline from Merom to the natural gas pipeline network. There is also an existing petroleum pipeline not too far to the north of Merom.

XII.8 Labor force availability

A synfuel park in the Merom area will probably be unable to draw all of its labor force from the local area. Additional personnel will likely need to be drawn from surrounding communities including Sullivan, Dugger and Terre Haute.

XII.9 Summary

In general, the Merom area is a good candidate site for developing a synfuel park. This site has several attractive features. Water resources appear sufficient to consider a fairly large scale operation, including SNG production if desired. Land is available in the area, and the infrastructure would only need moderate modification to accommodate the plant construction and operation. The economic scale of operations is probably in the range of 100,000 tons of coal per day, with outputs of up to 50,000 bpd of FT liquids and 200-300 MW of power export. SNG or hydrogen could also be produced at the expense of reduction of some of the other outputs.

XIII. Mount Vernon – The Port of Indiana at Mt. Vernon and CountryMark

Mount Vernon is a general location for a potential synfuel park/polygeneration plant. We evaluate two specific potential sites in the Mount Vernon area – the Port of Indiana at Mt. Vernon and the CountryMark Cooperative refinery facility.

The Port of Indiana at Mt. Vernon (PIMV) has been leasing land for commercial development, as shown in Figure XIII.2. The PIMV has rail inside the complex, plus several miles of surface roads that support trucks with gross weight in excess of 80,000 lbs. Utilities are also available for commercial development. Alliance Coal operates the facility, currently handling between one to two million tons annually. The facility is designed to handle approximately eight million tons per year. Coal can be transferred via a conveyor to barges on the Ohio River. However, due to the recent announcement of a new ethanol plant to be hosted in the PIMV complex, there may be insufficient additional land for a large synfuel park inside the complex. Nonetheless, farmland is potentially available to the east side of the site.

The CountryMark Coop has an oil refinery in the city, and the company has been thinking of expansion either in the refining of conventional oil or FT liquids. However, its current site is space constrained, limiting significant expansion. Agricultural land could potentially be acquired to accommodate an expansion. The context, topography and supporting infrastructure of the city are illustrated in Figures XIII.1-6, which shows that the location has access to water, rail and highway systems.

XIII.1 Coal availability

Currently, there is no Indiana coal production within 30 miles of Mt. Vernon. The nearest mine is the Rangeline mine in Warrick County, with no practical rail connection. However, the Discovery #2 Somerville South Pit about 35 miles away in Gibson County could provide coal via rail to a potential synfuel park in Mt. Vernon. Mines further north could also provide coal to a potential synfuel plant in Mt. Vernon.

In addition, there are substantial underground coal reserves in the Mt. Vernon area (Mastalerz & Kvale, 2000). The coal quality may be adequate for use in a synfuel park (see Table XIII.1). That is, if an underground mine were opened near Mt. Vernon to supply a potential synfuel park in the city, it would make the candidate site even more attractive. Of course, it may take three to four years for the new mine to be useable. However, the construction of a large synfuel park may take a similar amount of time.

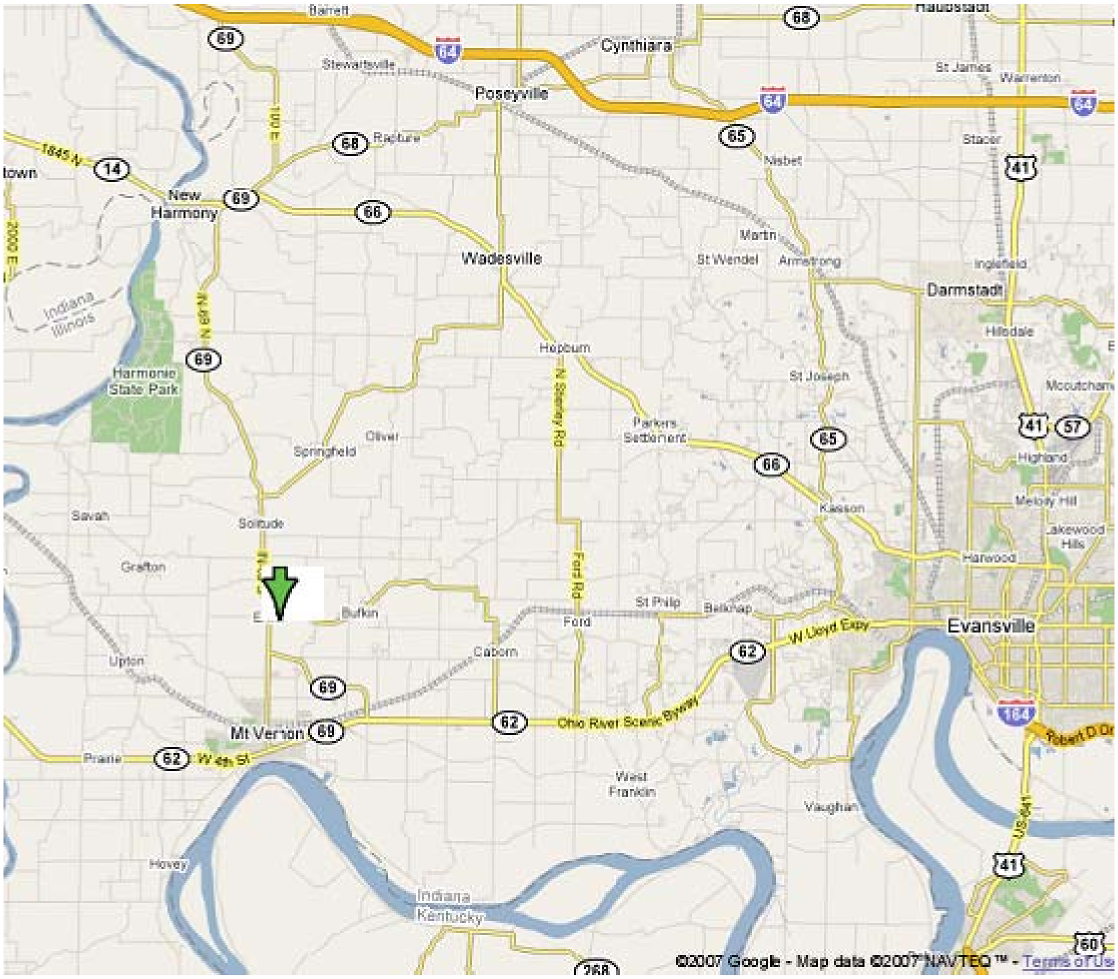


Figure XIII.1. Mount Vernon and neighborhood (Google Maps, 2007)

Figure XIII.2. Map of the Southwind Marine Center (Southwind Marine Center, Port of Indiana, 2007)

Figure XIII.3. Land topology near the Southwind Marine Center (Google Maps, 2007)

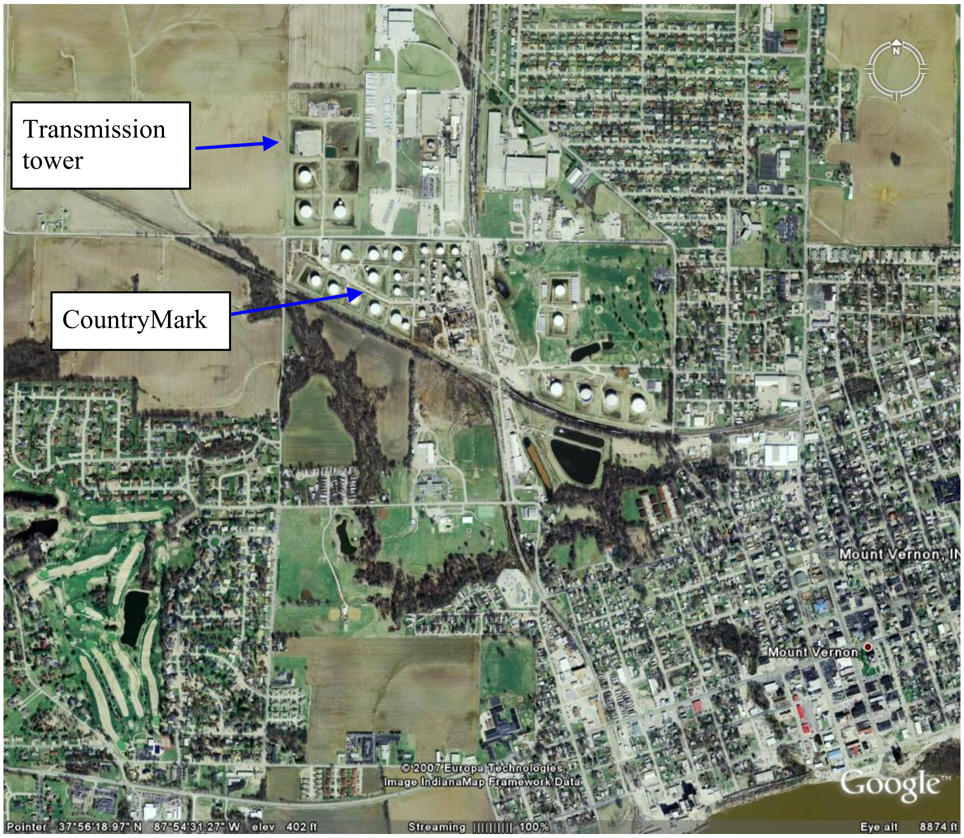


Figure XIII.4. Map of CountryMark Plant (Google Maps, 2007)

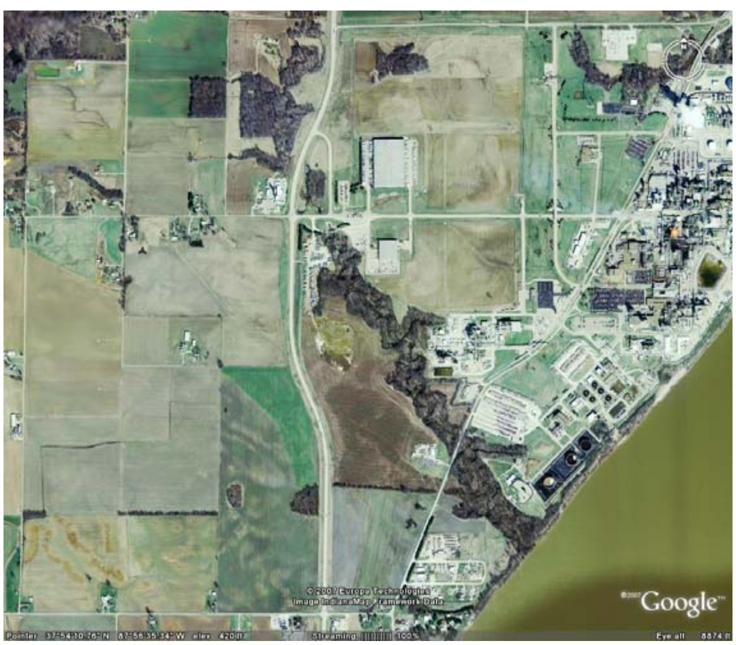


Figure XIII.5. The west side of Mt. Vernon (Google Maps, 2007)

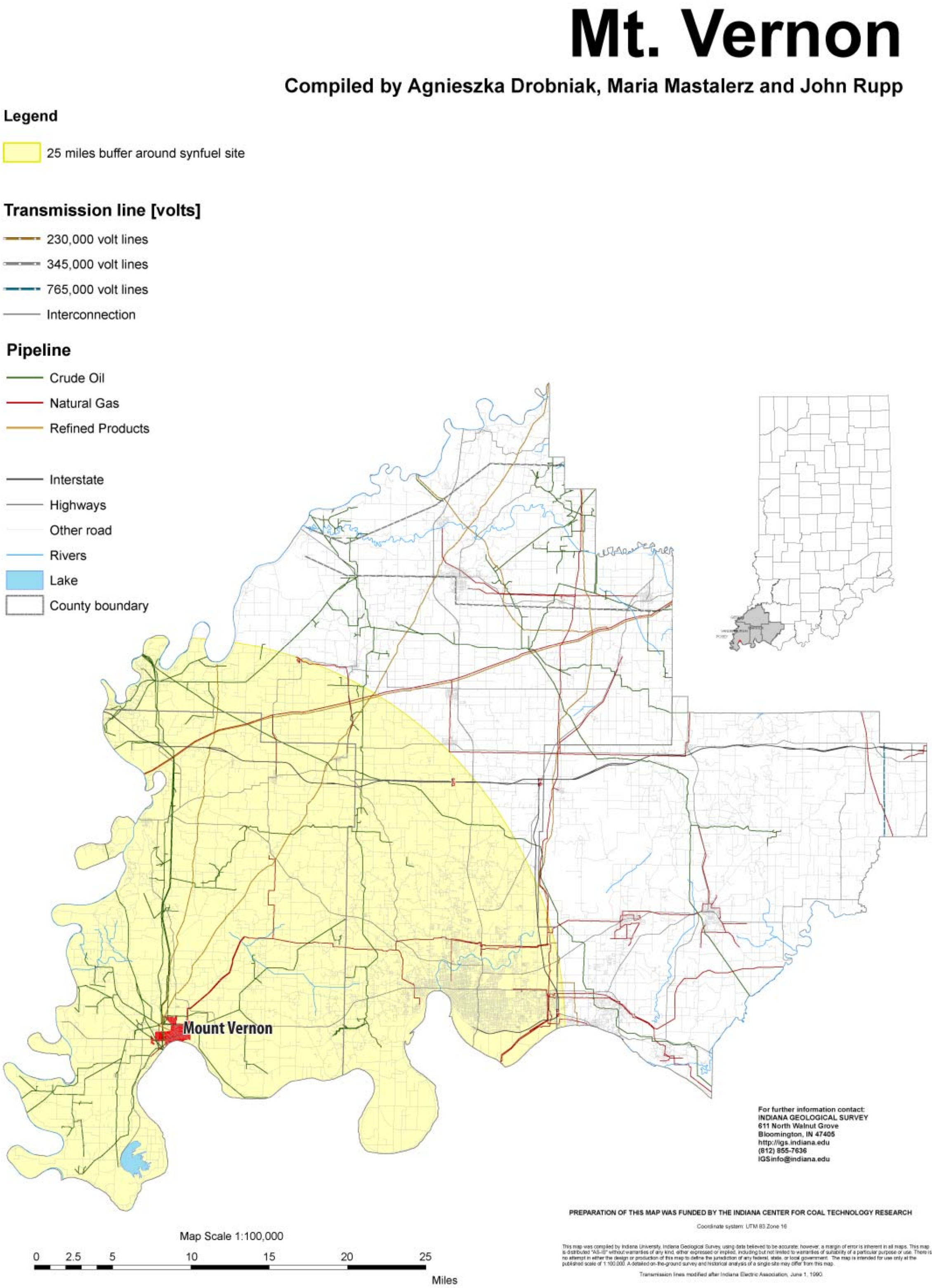


Figure XIII.6. Infrastructure in Mt. Vernon

Table XIII.1. Coal characteristics in a borehole near Mt. Vernon (Mastalerz & Kvale, 2000)
(Coal properties from borehole SDH-383, a few miles north of Mt. Vernon)

Sample	Depth (ft)	Moisture (%)	Ash dry (%)	S dry (%)	Btu dry	Btu daf	Coal	Seam thickness (ft)
C98126-1	494.4-495.3	11.29	10.6	3.92	12770	14284	Danville	2.9
C98126-2	505.7-506.4	8.67	20.7	5.52	10688	13821	Hymera	0.7
C198126-3	546.3-548.3	10.68	10.47	4.12	12751	14242	Herrin	5.8
C98126-4	625.6-627.6	8.45	15.84	8.22	11782	14000	Springfield	2.6
C98126-5	740.4-742.7	8.61	14.19	4.22	12122	14127	Houchin Creek	2.3
C98126-6	791.8-792.8	10.56	11.92	1.82	12678	14394	Survant	1
C98126-7	867.5-868.4	4.96	22.76	8.45	10961	14191	Colchester	0.9
C98126-8	896.6-897.6	7.89	11.28	6.29	12819	14449	Seelyville	1.5
C98126-9	905-907	5.59	15.34	7.91	12083	14272	Seelyville	3.7
C98126-10	970.35-971.35	8.58	21.74	8.39	11191	14300	Holland	1
C98126-11	1124-1125	6.73	8.28	5.23	13497	14715	Buffaloville	1.15
C98126-12	1178.2-1179.2	8.45	15	3.11	12313	14486	Lower Block	1.65

XIII.2 CO_2 sequestration potential

There are four potential options for geological sequestration of CO_2 from a gasification facility in the Mt. Vernon area: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production, and injection into deep saline water-filled aquifers. Detailed results of the quantitative assessment are presented in sections E.4 of the appendix.

It appears that 693 million scf of enhanced coal bed methane could be produced with a potential storage of over 30 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 275 million standard barrels (stb) of crude oil and the potential to sequester 76 million tons of CO_2. Over 3.7 billion scf of enhanced shale gas could potentially be recovered with the flooding of about 1.4 billion tons of CO_2. Injection into deep saline water-filled aquifers has the potential for the sequestration of another 375 million tons. Thus, there are several potential options for geological sequestration of CO_2 in the Mt. Vernon area, with the greatest potential capacity in shale deposits and deep saline-filled aquifers.

XIII.3 Transportation infrastructure/logistics

The Center is connected via rail systems with Evansville to the east, and with St. Louis to the west. As noted earlier, three processes require use of the transportation infrastructure: (1) shipment of large components of the polygeneration plant, (2) the transportation of coal to the potential synfuel park, and (3) the distribution of finished products.

XIII.3.1 Shipment of large pieces of equipment to Mt. Vernon

Mt. Vernon has a great advantage over the other sites in terms of handling large equipment such as large FT reactors. The PIMV (Figure XIII.7) has a crane that can handle a load of about 60 tons at a time. However, a crane located at the BWX Technologies facility about two miles downstream of the port can handle a load of 1,000 tons. Larger cranes could be borrowed from other locations. This capacity to handle large equipment makes it feasible to consider designing the plant to take advantage of the economies of scale of FT reactors in particular, which have higher yields per unit of syngas with larger reactors. The use of larger reactors, as well as larger gasifiers and refining facilities, would also allow a reduction in land requirements for the facility.

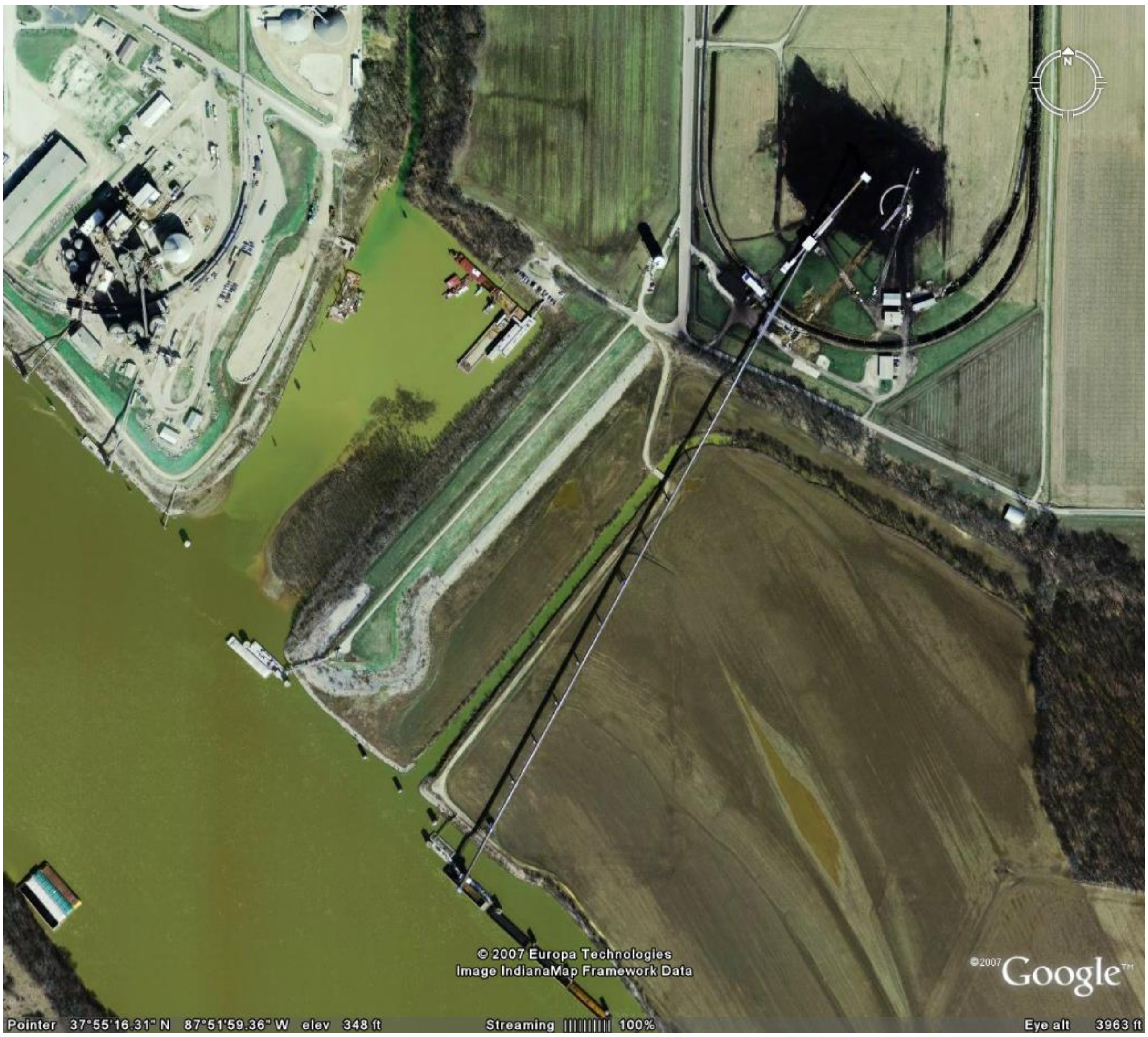


Figure XIII.7. Port of Indiana at Mt. Vernon Coal Handling Facility (Google Maps, 2007)

XIII.3.2 Transportation of coal to Mt. Vernon

A synfuel park in the Mt. Vernon area could take advantage of the coal handling facility at the PIMV to accommodate coal shipments either by rail or barge. If the park is located at the CountryMark refinery site, then land will need to be allocated for coal handling unless some cooperative arrangement can be made with the PIMV. There may be congestion in the rail system if the coal processing volume is large..

XIII.3.3 Transportation of finished products from Mt. Vernon

Primary finished products of a synfuel park are likely to be FT diesel, gasoline, military fuel(s), naphtha, SNG and/or hydrogen. Sulfur is a byproduct that can be sold or given away for use in fertilizer production. Except SNG and power, other products can be shipped via rail and trucks. However, since the Mt. Vernon sites are on the Ohio River, waterways may be the most cost-effective means for transporting finished products to various parts of the country, and even to international markets, as shown in Figure XIII.8.

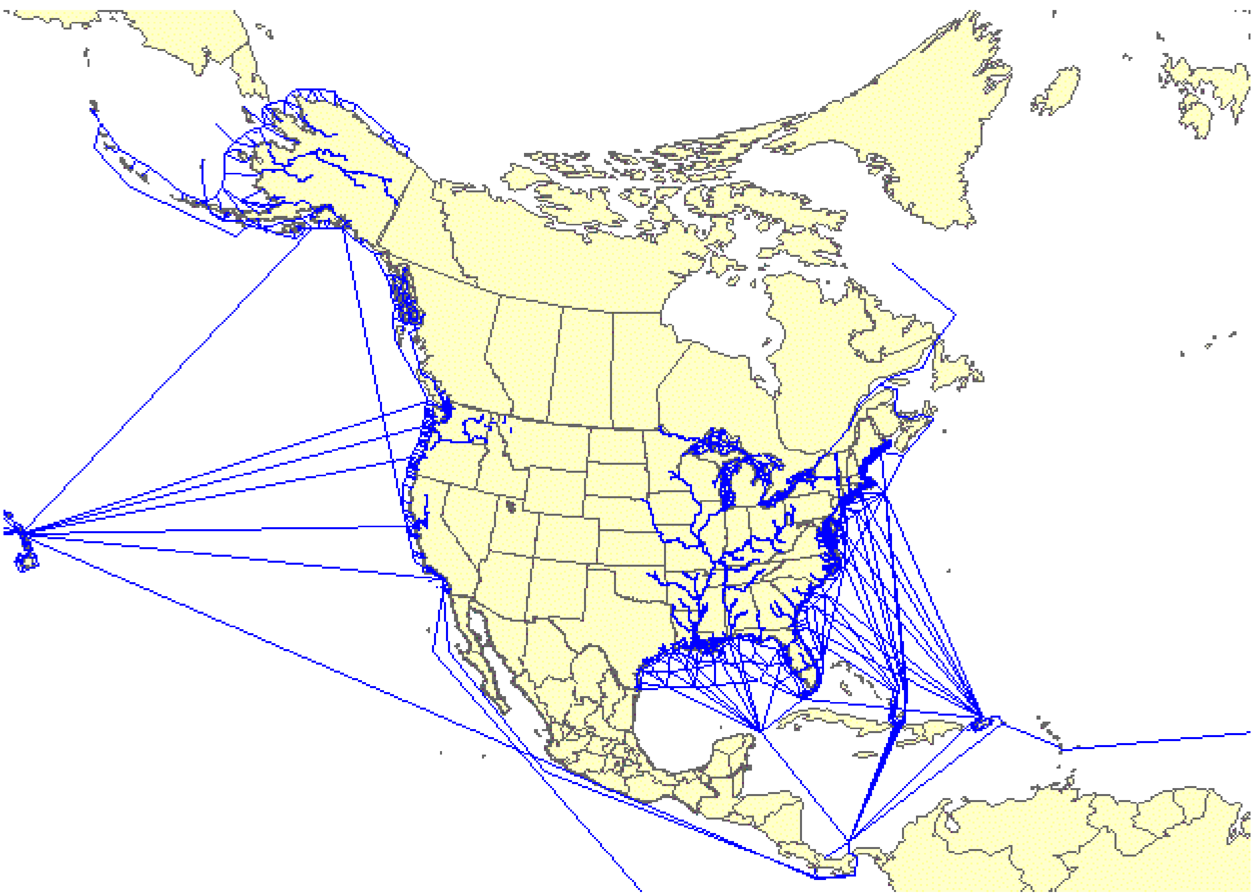


Figure XIII.8. U.S. Water Network (U.S. Army Corp of Engineers, n.d.)

XIII.3.4 Transportation of slag/ash from Mt. Vernon

Because both sites are adjacent to the city of Mount Vernon, it will be desirable to dispose of slag/ash off site. There is a hilly area (see Figure XIII.3) a few miles north of the city, and slag/ash could be trucked there for disposal. Alternatively, if a mine is opened in the Mount Vernon area, slag/ash could potentially be returned to the mine for storage. However, this would require a regulatory change since the State of Indiana does not allow ash to be stored in underground mines even if they are mined out. (Current regulations only allow slag/ash to be returned to mined out surface mines.)

XIII.4 Water requirements and resources

The primary source of water in the Mt. Vernon area is the Ohio River. The historical average stream flow rate at Evansville (the closest USGS monitoring station) is shown in Table XIII.2. There is also substantial underground water along the Ohio River, which may be useful in steam generation. This table shows that even in the driest month of October, the lowest average stream flow is still 27,100 cfs on October 16, which is equivalent to 415,683,858 bpd. That is, water is still sufficient for a very large synfuel park/polygeneration plant even during the dry season. Even for a synfuel park with 100,000 bpd of FT liquids and significant power export, the water withdrawn is likely to be less than 1% of the Ohio River stream flow. Even if a considerable amount of SNG is produced, the water supply is still sufficient. Note that the gauge height of the river varies considerably during the year. This will have implications for the design of the water pumping system and energy requirements (see Table XIII.3).

XIII.5 Land/ real estate requirements

As noted in the section on transportation infrastructure, one advantage of a Mount Vernon site for a synfuel park is its ability to accept large equipment. Because of economies of scale in conversion, the use of larger units (particularly reactors and gasifiers) will result in a smaller footprint for the plant. The capacity range is likely to be larger for the PIMV site than for the CountryMark site, with a coal conversion per day of 100,000-200,000 tons at PIMV versus 40,000-60,000 tons at MC. The difference in capacity relates primarily to the proximity to the Ohio River, which facilitates water availability, coal handling capacity, and the scale of operations (through the ability to make use of larger equipment at PIMV).

XIII.6 Transmission lines and power availability

The supporting infrastructure in the Mt Vernon area is displayed in Figure XIII.6. No large capacity power transmission lines connect to the Mt. Vernon area. The nearest significant power substation is the Vectren A.B. Brown Station, which is about 10 miles to the east near the Ohio River. However, lower level transmission lines in the area could potentially be expanded. In order to export large amounts of power to the grid from the Mt. Vernon area, one would need to construct a substation and HV transmission lines that can be connected to the Gibson power station about 30 miles to the north or the Brown power station about 10 miles to the east. Alternatively, the output mix of the synfuel park could be shifted to export less power.

XIII.7 Gas and oil pipelines

There are oil, diesel and small gas pipelines in Mt. Vernon, as indicated in Figure XIII.6. CountryMark owns the oil and diesel lines. Availability of these pipelines would simplify delivery of finished products. Major gas pipelines are also close by, enabling the production and sale of SNG.

Table XIII.2. Average Ohio River stream flow at Evansville near Mt. Vernon (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	Mean of daily mean values for each day for 34 years of record, in cfs (Calculation Period 1940-10-01 -> 1974-09-30) Calculation period restricted by USGS staff due to special conditions at/near site											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	156,000	212,000	229,000	269,000	196,000	125,000	75,400	56,200	33,300	35,100	39,700	101,000
2	164,000	218,000	229,000	264,000	195,000	128,000	73,500	56,600	33,900	36,000	41,900	103,000
3	176,000	221,000	233,000	261,000	195,000	126,000	70,500	56,400	35,200	37,400	45,900	105,000
4	188,000	221,000	241,000	258,000	193,000	126,000	66,700	56,300	36,200	37,100	48,100	106,000
5	198,000	221,000	250,000	256,000	189,000	125,000	65,400	55,000	35,600	35,800	49,300	107,000
6	207,000	222,000	266,000	257,000	182,000	121,000	64,700	56,300	35,300	33,000	56,100	108,000
7	212,000	227,000	278,000	254,000	176,000	117,000	65,100	56,900	35,000	31,500	58,000	107,000
8	214,000	230,000	290,000	254,000	174,000	112,000	62,800	55,100	34,100	33,500	58,600	109,000
9	213,000	228,000	300,000	255,000	174,000	108,000	61,300	54,500	32,800	34,200	57,600	114,000
10	211,000	226,000	306,000	256,000	174,000	103,000	61,500	54,000	30,600	32,200	57,800	120,000
11	208,000	226,000	313,000	258,000	176,000	97,800	63,400	51,700	28,900	30,000	56,600	130,000
12	203,000	227,000	316,000	260,000	174,000	95,700	65,300	49,500	30,400	29,000	58,100	138,000
13	196,000	228,000	318,000	264,000	174,000	92,400	63,800	51,400	31,600	29,300	59,200	144,000
14	192,000	228,000	318,000	264,000	175,000	88,900	61,100	52,500	32,400	28,600	61,100	150,000
15	187,000	232,000	316,000	262,000	176,000	87,100	58,400	50,300	33,600	28,500	63,700	153,000
16	185,000	239,000	315,000	259,000	177,000	88,300	56,100	46,900	33,400	27,100	66,000	155,000
17	184,000	243,000	317,000	256,000	179,000	89,600	56,400	45,900	34,300	28,100	62,600	156,000
18	183,000	246,000	321,000	253,000	179,000	90,000	56,500	42,800	33,700	27,900	63,400	157,000
19	179,000	248,000	324,000	249,000	179,000	92,000	54,400	41,600	31,700	27,800	65,700	154,000
20	174,000	247,000	324,000	245,000	177,000	95,900	57,000	41,400	30,600	29,200	71,400	149,000
21	171,000	243,000	323,000	238,000	170,000	94,400	57,300	39,200	32,700	33,200	77,100	141,000
22	172,000	240,000	323,000	232,000	164,000	94,200	61,200	39,600	33,900	35,100	80,400	138,000
23	176,000	237,000	323,000	226,000	158,000	92,300	66,100	40,400	35,500	36,600	81,900	137,000
24	182,000	233,000	318,000	221,000	152,000	89,800	67,800	41,200	37,700	37,200	83,000	137,000
25	187,000	229,000	313,000	215,000	147,000	90,600	64,100	40,100	39,000	37,200	85,200	140,000
26	189,000	226,000	307,000	210,000	144,000	86,400	61,600	36,000	36,300	38,600	92,300	145,000
27	194,000	225,000	303,000	206,000	141,000	84,800	61,800	35,900	35,900	37,700	92,300	145,000
28	197,000	227,000	299,000	203,000	138,000	84,300	59,700	35,800	35,100	36,700	92,800	144,000
29	199,000	252,000	293,000	201,000	134,000	84,800	58,800	35,900	34,400	34,800	95,500	144,000
30	202,000		286,000	197,000	130,000	81,500	57,200	38,000	33,900	33,500	99,000	145,000
31	208,000		277,000		126,000		57,700	38,200		32,400		150,000

Table XIII.3. Average gauge height of the Ohio River at Evansville (U.S. Department of the Interior, U.S. Geological Survey, 2006)

Day of month	**Mean of daily mean values for each day for 4 - 5 years of record, in feet (Calculation Period 1986-10-01 -> 2000-09-30)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	21.80	19.66	27.02	21.71	21.92	22.31	16.16	14.24	14.35	14.43	13.98	20.06
2	21.33	21.59	25.78	22.63	21.47	22.13	16.23	14.47	14.39	14.15	14.16	19.61
3	21.42	24.35	24.77	23.49	20.78	21.42	16.56	14.20	14.21	14.37	14.26	19.45
4	22.90	25.71	24.39	24.54	20.37	20.65	16.32	14.08	13.80	15.16	14.35	19.41
5	23.71	26.84	24.38	26.30	20.25	20.06	16.23	14.31	**13.60**	15.51	14.42	19.14
6	23.59	27.48	24.86	27.28	20.64	19.27	16.63	14.23	13.70	15.83	14.58	18.89
7	22.57	27.95	25.49	28.02	21.22	18.52	16.12	14.72	13.86	15.98	14.75	18.62
8	21.37	27.93	25.84	28.88	21.29	18.13	16.37	15.07	14.01	15.51	15.00	18.60
9	20.94	27.34	25.73	29.84	21.13	17.91	16.21	15.37	14.25	15.51	15.38	18.23
10	19.39	25.87	24.76	30.67	21.04	17.22	15.36	15.12	14.55	15.13	16.06	17.83
11	18.33	24.46	23.58	31.29	20.88	16.83	15.06	14.97	14.39	14.61	17.07	17.98
12	17.41	23.26	23.04	31.29	20.47	16.91	15.29	15.14	14.22	14.39	17.81	18.14
13	16.88	22.42	23.14	30.61	19.70	17.17	16.07	14.97	14.39	14.47	18.27	18.59
14	16.97	23.80	22.64	29.73	19.96	17.46	16.32	14.43	14.32	13.99	18.25	19.14
15	16.40	26.21	21.75	28.85	20.27	17.87	16.68	14.15	14.37	14.10	17.63	19.41
16	16.04	28.21	21.20	27.58	20.27	17.50	16.92	14.01	14.54	14.25	17.29	19.45
17	15.73	29.60	21.20	26.06	21.23	18.05	16.95	13.84	14.78	14.16	17.07	19.28
18	15.45	30.55	20.49	24.51	22.44	19.48	17.06	13.90	14.92	14.49	16.72	18.77
19	15.67	31.45	19.82	23.45	22.73	20.55	16.85	14.02	15.95	14.89	17.10	17.97
20	18.44	32.16	20.32	23.23	22.62	20.86	16.54	13.87	15.90	15.52	17.77	17.16
21	21.54	32.77	21.49	23.72	22.50	20.74	16.44	14.29	15.29	16.24	18.84	16.33
22	23.79	**32.99**	22.45	24.36	22.54	20.35	16.81	14.41	14.62	16.92	19.51	15.75
23	25.01	32.92	22.84	24.40	22.08	20.16	16.27	14.52	14.49	17.45	19.55	15.74
24	25.85	32.74	22.71	23.61	21.49	19.73	15.59	14.95	14.55	17.29	19.42	16.13
25	25.78	32.51	22.62	22.42	21.11	19.52	15.28	15.38	15.47	16.83	19.00	16.80
26	22.89	32.02	22.38	21.06	20.78	19.48	15.57	15.58	16.71	15.99	18.15	18.29
27	20.80	31.08	21.87	20.61	20.73	18.89	15.61	15.66	17.43	14.81	18.28	19.71
28	19.05	29.41	20.90	20.31	20.88	18.22	15.41	15.51	17.26	14.40	18.89	21.39
29	18.43	24.91	20.20	21.29	21.53	16.74	14.92	14.82	16.49	14.31	19.46	22.81
30	18.27		19.97	21.70	22.15	16.44	14.64	14.51	15.59	14.22	20.09	23.02
31	18.62		20.63		22.34		14.77	14.63		14.12		22.50

XIII.8 Labor force availability

A synfuel park in the Mount Vernon area could draw some of its workforce from the city itself. Additional personnel could be attracted from Evansville and other neighboring communities.

XIII.9 Summary

The Mount Vernon area has several advantages as a location for a synfuel park. The Ohio River is chief among these advantages in that it provides a ready source of water, as well as the prospect of transportation via water of large equipment during the construction phase and both coal inputs and plant outputs during the operation phase. While active coal mines are not located close by, there are prospects both for shipping coal to the site by rail or barge or for opening a mine in the area. In addition, there is a coal handling facility already in the area as well as a refinery. Infrastructure appears to be good, although some upgrading of the connection to the electricity grid may be needed. It appears that a facility processing 40,000-200,000 tons of coal per day could be supported with outputs of 20,000-100,000 FT liquids and 200-600 MW of power export. Due to limitations on the grid connections, an output mix involving less power export may be advantageous, and with the ample water supply, inclusion of SNG or hydrogen in the output mix may be desirable.

XIV. Minnehaha

The Minnehaha region is a relatively large area stretching a few miles south from the city of Dugger. The Black Beauty Coal Company may open a mine in the region in the near future. Figures XIV.1-3 show the context, topography and supporting infrastructure in the area.

XIV.1 Coal availability

There are substantial coal reserves on site at Minnehaha. The Black Beauty Coal Company expects to open the Minnehaha surface mine, which could provide coal to a potential synfuel park there. In addition, some nearby mines can also supply coal to the potential plant, including the Kindill #3 Penndiana Pit in Sullivan County. One of the chief advantages of the Minnehaha site is the ready availability of coal.

XIV.2 CO_2 sequestration potential

There are four potential options for geological sequestration of CO_2 from a gasification facility in the Minnehaha area: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production, and injection into deep saline water-filled aquifers. Detailed results of the quantitative assessment are presented in sections E.4 of the appendix.

It appears that 132 million scf of enhanced coal bed methane could be produced with a potential storage of over 6 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 91 million standard barrels (stb) of crude oil and the potential to sequester 17 million tons of CO_2. Over 1.5 billion scf of enhanced shale gas could potentially be recovered with the flooding of about 0.6 billion tons of CO_2. Injection into deep saline water-filled aquifers has the potential for the sequestration of another 15.8 billion tons. Thus, there are several potential options for geological sequestration of CO_2 in the Minnehaha area, with the greatest potential capacity in deep saline-filled aquifers and shale deposits.

Figure XIV.1. Map of the Minnehaha area (Google Maps, 2007)

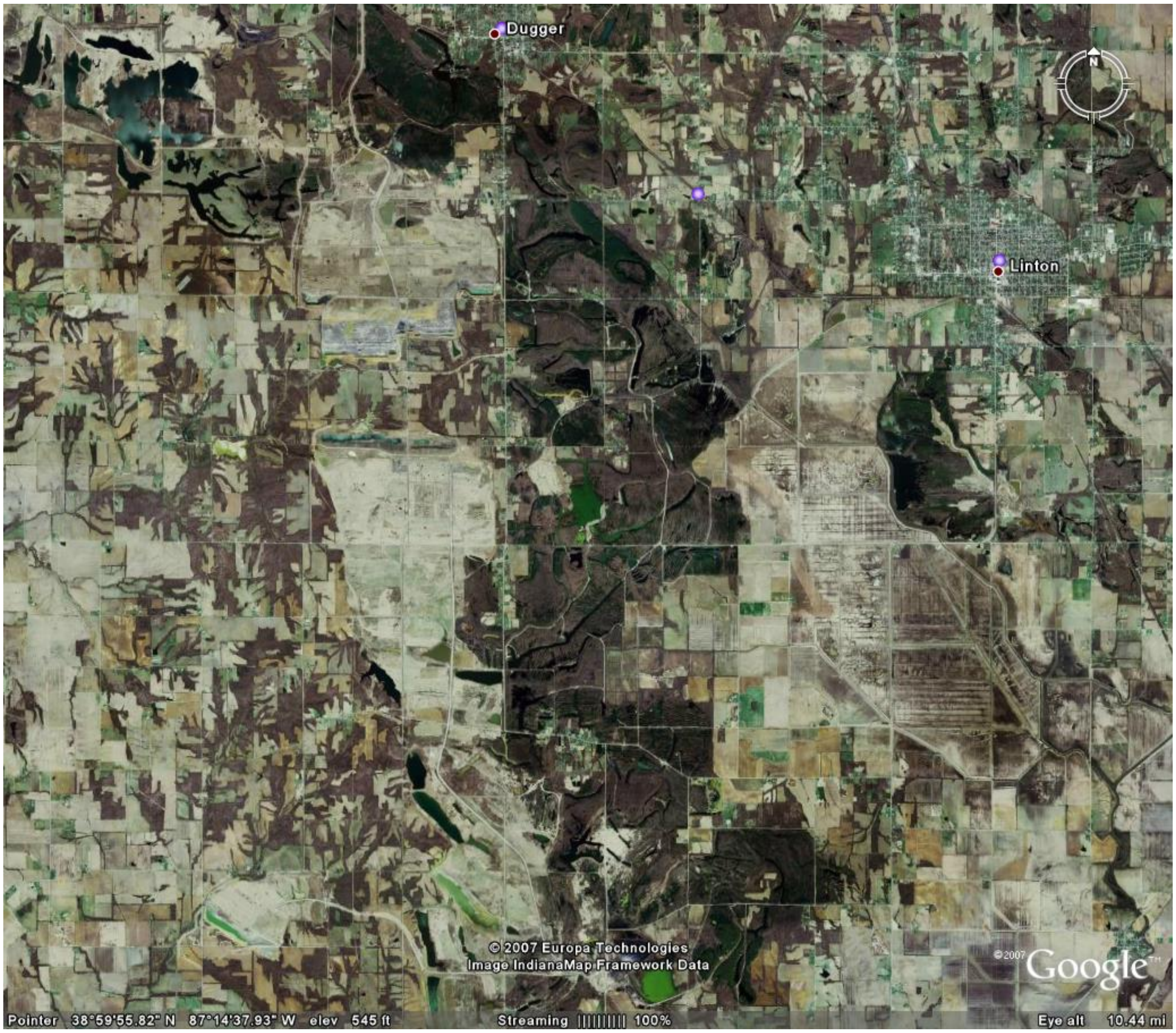


Figure XIV.2. Land topography near the Dugger area (Google Maps, 2007)

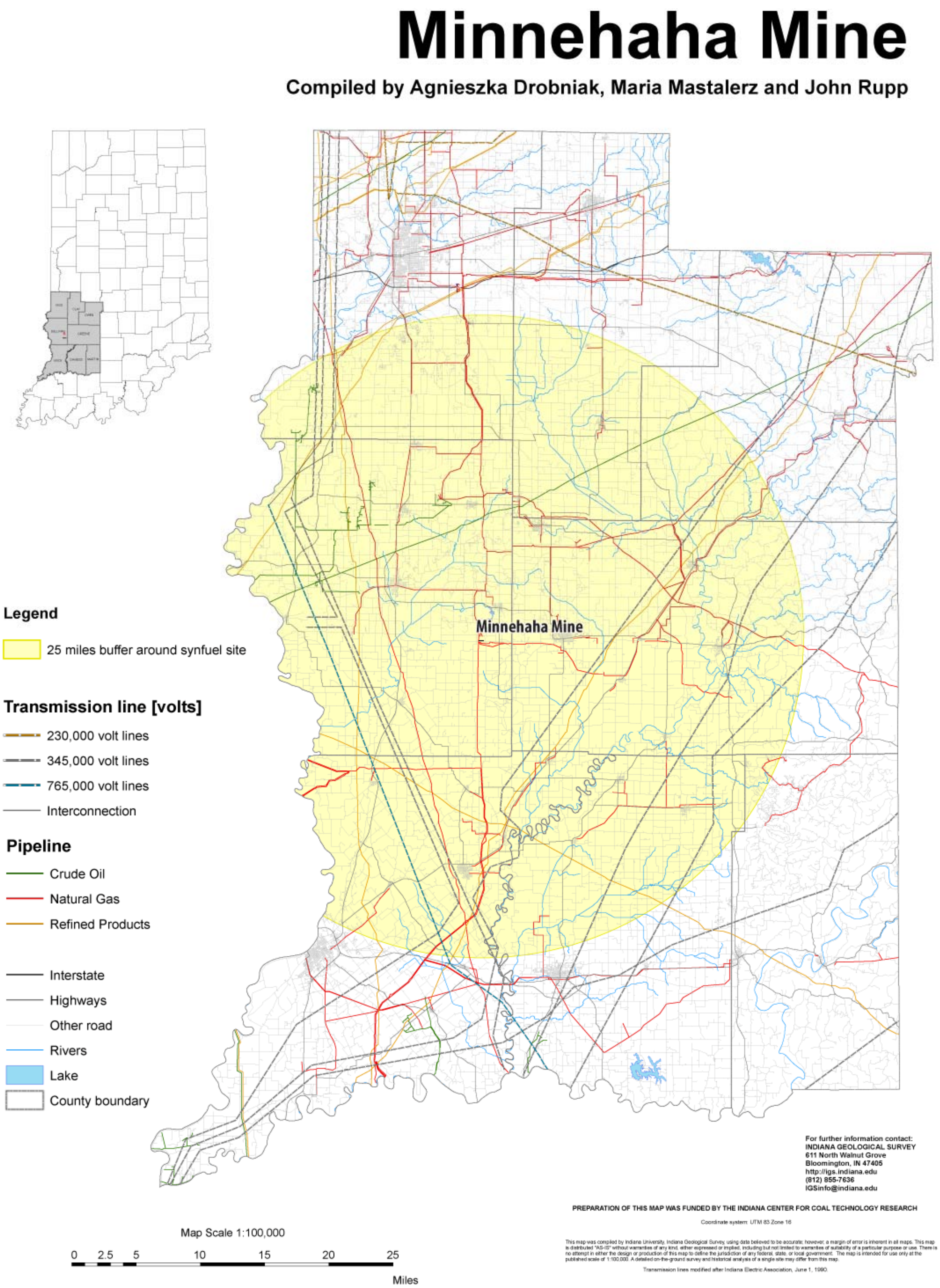


Figure XIV.3. Infrastructure in the Minnehaha area

XIV.3 Transportation infrastructure/logistics

Transportation infrastructure is required for: (1) shipment of large components of the synfuel plant, (2) the transportation of coal to the potential synfuel park, and (3) the distribution of finished products.

XIV.3.1 Shipment of large pieces of equipment to Minnehaha

As indicated in section IV on regional transportation infrastructure, the probable mode of delivery for large equipment is to a port on the Ohio River with Evansville as the most likely candidate due to its relative proximity to Minnehaha. Once unloaded at Evansville, large equipment is best delivered via rail. There are at least 16 overpasses and bridges between Evansville and Sullivan. There is at least one additional overpass between Sullivan and Dugger, plus a few bridges to negotiate. As an alternative, a rail line extends from Dugger to Linton, to the small town of Sandborn, and then back towards Dugger without overpasses. This route ends somewhere south of the Kindill #3 site and could be used for large equipment transportation.

XIV.3.2 Transportation of coal to Minnehaha

As noted in section XIV.1, a chief advantage of Minnehaha is its proximity to coal. If the Minnehaha mine is opened, then coal could be delivered to the synfuel plant either by truck or conveyor. The situation would be similar if coal were sourced from the Kindill #3 mine

XIV.3.3 Transportation of finished products from Minnehaha

Primary finished products of a synfuel park are likely to be FT diesel, gasoline, military fuel(s), naphtha, SNG and/or hydrogen. Sulfur is a byproduct that can be sold or given away for use in fertilizer production. These products can be shipped via rail. State highways can also be used for small quantities of product shipment.

XIV.3.4 Transportation of slag/ash from Minnehaha

Slag/ash can be trucked to a nearby location, such as mined-out strip mines in the area. There are several such sites scattered around the Minnehaha region, as shown in Figure XIV.2, and they may be economically attractive for slag/ash disposal.

XIV.4 Water requirements and resources

Water resources are very limited in the area surrounding the Minnehaha mine. There is no significant water way nearby, and underground water is not plentiful. Some water has accumulated in strip mines in the area, but these resources are unlikely to provide a long-term, reliable water supply. Even if a dry cooling system were designed for the plant, the water requirements would still exceed what is available in the area. One way to solve the water availability problem is to obtain water from the Wabash River about 15 miles away by constructing a large water pipeline or canal. This would represent a substantial cost.

XIV.5 Land/ real estate requirements

Generally the greatest need for land for a synfuel park is land for disposing of slag/ash. Given the abundance of mined-out strip mines in the area, this requirement is easily met. This type of land could also be used for the main plant, coal storage and handling areas, etc. Thus, if the plant is located at Minnehaha, the cost of land acquisition is likely to be a relatively small part of its total cost.

XIV.6 Transmission lines and power availability

There is neither a power substation nor transmission lines in the area (see Figure XIV.3). If power export were part of the output of the potential synfuel park, a substation and transmission lines would have to be built. This would also represent a substantial cost.

XIV.7 Gas and oil pipelines

A gas pipeline runs quite close to the site, and an oil pipeline is located less than ten miles north of the site, as indicated in Figure XIV.3. These could be extended to the Minnehaha site at moderate cost. Pipelines for finished products could possibly be piggybacked on these other pipelines.

XIV.8 Labor force availability

A synfuel park at Minnehaha probably could not draw all of its labor force from Dugger, Linton, and the other small communities in the area. Some of the personnel would likely need to be sourced from Terre Haute, Vincennes and Bloomington.

XIV.9 Summary

The main advantages of Minnehaha as a potential synfuel park site are the proximity of coal inputs and the availability of low value land. The principal difficulties with establishing a synfuel park at the Minnehaha site are the limited water availability, limitations on the transportation infrastructure, and a need to upgrade the links to the electricity grid. These features limit the economical scale of operations. The economical scale of operations is probably in the range of 20-40,000 tons per day of coal input with outputs of 10-20,000 bpd of FT liquids and 50-100 MW of power export. Due to the limited availability of water, SNG and hydrogen production are not recommended.

XV. NSA Crane in Martin County

A preliminary feasibility study for a synfuel park located at NSA Crane was completed in May 2007. For completeness, we draw on that report in order to include NSA Crane in the list of sites in this report. However, we will summarize briefly the major points, and the reader should refer to the earlier report for further details (Irwin et al., 2007). NSA Crane is a military facility located in Martin County to the southeast of the city of Crane. The context of the site is illustrated in Figure XV.1.

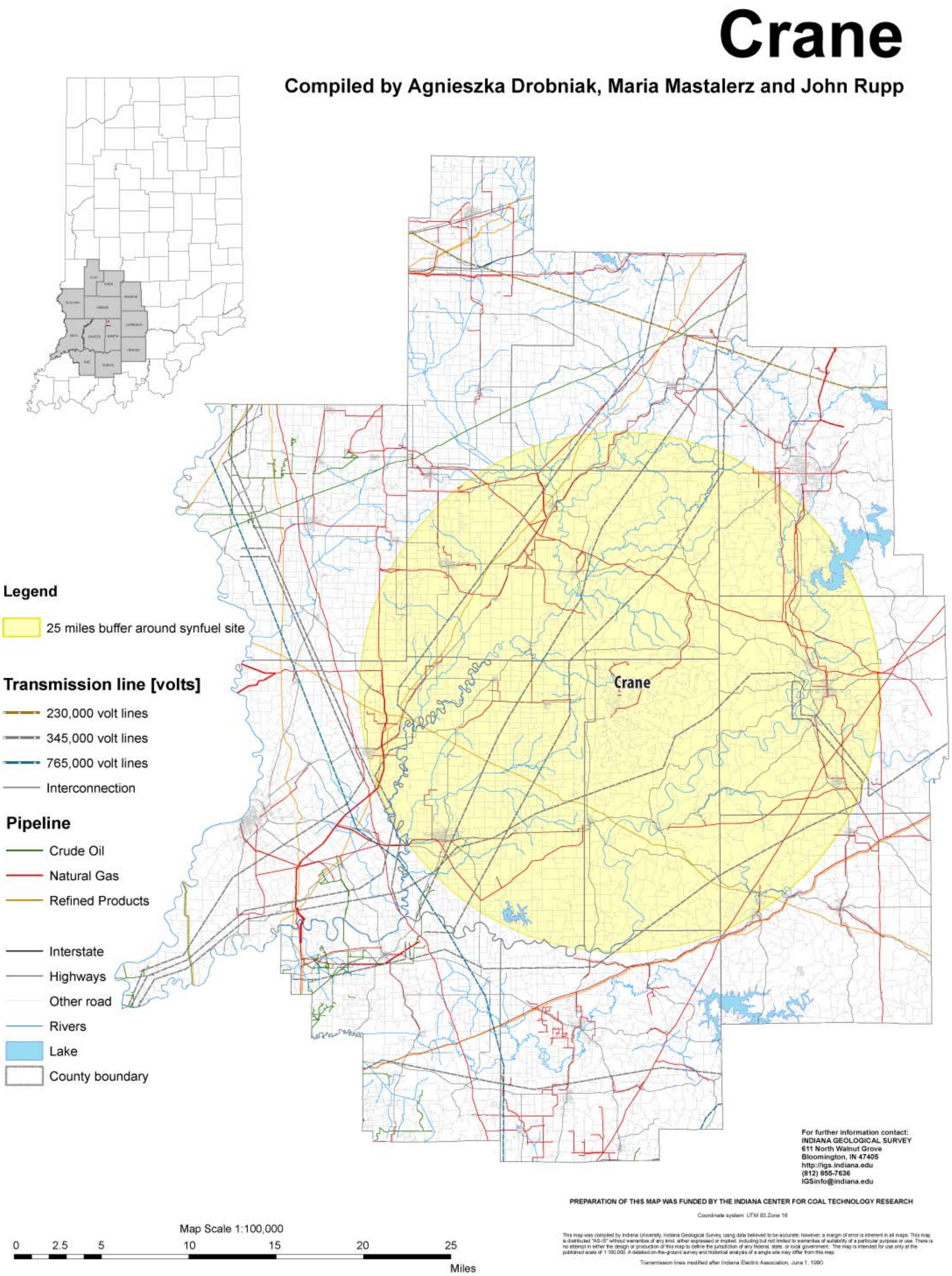


Figure XV.1. NSA Crane and the 25 mile surrounding area (Irwin et al., 2007)

XV.1 Coal availability

Crane NSA is about 12-15 miles from two major mines in Daviess County. Mines in other adjacent counties to the west could also supply coal to a potential synfuel park/polygeneration plant at Crane.

Table XV.1. Coal distribution of the Danville and Springfield seams (Irwin et al., 2007)

County	Mining Type	DANVILLE Coal Bed	SPRINGFIELD Coal Bed	D + S
Daviess	Surface	0.00	16.59	16.59
	Underground	-	0.00	0.00
Gibson	Surface	43.91	95.53	139.44
	Underground	36.35	**1,930.91**	**1,967.26**
Greene	Surface	0.69	70.17	70.86
	Underground	-	5.68	5.68
Knox	Surface	51.63	55.49	107.12
	Underground	228.35	**1,072.42**	**1,300.77**
Pike	Surface	9.75	160.68	170.43
	Underground	0.00	175.11	175.11
Posey	Surface	0.00	-	0.00
	Underground	0.00	**1,527.61**	**1,527.61**
Sullivan	Surface	78.95	72.64	151.59
	Underground	108.11	741.72	849.83
Vanderburgh	Surface	0.07	0.00	0.07
	Underground	0.00	516.07	516.07
Vermillion	Surface	12.03	5.23	17.26
	Underground	11.70	21.12	32.82
Vigo	Surface	98.75	48.30	147.05
	Underground	137.82	335.26	473.08
Warwick	Surface	53.97	295.48	349.45
	Underground	0.00	608.78	608.78
TOTAL	**Surface**	**349.75**	**820.11**	**1,169.86**
	Underground	**522.32**	**6,934.68**	**7,457.00**

XV.2 CO_2 sequestration potential

Crane NSA lies in an area abundant in New Albany shale, yielding good potential for ESG recovery and related CO_2 sequestration. Small oil fields in the area could also be used for EOR (Table XV.2). In addition, there is potential for ECBM to the west. Finally, sequestration in aquifers is a substantial possibility. Detailed results of the sequestration analysis of this site were reported in Irwin et al. (2007).

Table XV.2. Sequestration potentials associated with ESG and EOR at NSA Crane

Reservoirs	CO2 Storage	Methane Recovery	Enhanced Oil/Gas Recovery
Saline Reservoirs	CO2 Storage Capacity (MMt)		
Mt. Simon Sandstone	15,355		
St. Peter Sandstone	210		
Total	15,565		
Oil & Gas	CO2 Storage Capacity (MMt)		EOR (standard barrels)
Petroleum Fields	0.67		3,828,039
Shale	CO2 Storage Capacity (MMt)	Shale Gas (MMscf)	Enhanced Shale Gas (MMscf)
New Albany Shale	572	10,004	1,500

XV.3 Transportation infrastructure/ logistics

The site is well connected via rail, and there is a significant rail network on the NSA Crane grounds. An east-west rail runs through the site, and a south-north rail line is not far away. The planned path of the interstate highway I-69 passes by the northwest corner of the site, and this new highway would provide an added means of transportation. As with many of the sites that are not on a navigable river, transportation of large equipment is a problem that will have to be solved and that may limit the economic scale of operations.

XV.4 Water requirements and resources

Water is limited at NSA Crane. Lake Greenwood has a capacity of about 3.5 billion gal of water. However, this water is used as the main water source for the base and nearby communities. Thus, this lake is probably not an appropriate source of water for a synfuel park.

However, there are other water sources, including the East Fork and West Fork of the White River, and Lake West Boggs. The East Fork alone is capable of providing enough water for a small to moderate sized synfuel park, as shown in Table XV.3. The precise location of the synfuel park within NSA Crane will determine whether a large pipe system or canal would have to be constructed to supply the plant and, if so, its length.

Table XV.3. Percent water withdrawn from the east fork (based on daily flow)

	5,000 B/D FT 41 MW export	10,000 B/D FT 82 MW export	15,000 B/D FT 123 MW export
Average flow 5,000 cfs	0.1%	0.2%	0.3%
Low flow 1,280 cfs	0.39%	0.78%	1.17%

XV.5 Land/ real estate requirements

Crane NSA encompasses an area of about 63,000 acres, with isolated flat areas. For a plant size from 10,000 bpd to 20,000 bpd, plus some power export, a synfuel park may use no more than 300 acres for hosting the main plant. Slag and ash disposal may need less than 1,000 acres, or even 500 acres if deep valleys are used. Thus, land availability is not a constraint; however, determining what land within the site to dedicate to the main plant and what land to slag and ash disposal may be a challenge.

XV.6 Transmission lines and power availability

Three 345 kilovolt transmission lines run close by the site. Several lower kilovolt lines also pass through the site (Figure XV.2). Crane is connected to both the Duke Energy Indiana and Hoosier Energy transmission systems, with a peak demand around 26 MW. Thus, it appears that adequate power would be available for construction, and that the transmission system would allow for a certain amount of power to be exported without having to upgrade the system. A detailed connectivity study, especially a stability study, may be needed to evaluate the feasibility of a large amount of power export.

XV.7 Gas and oil pipelines

The site is connected to the Texas Gas Trans Corporation pipeline via a small gas pipeline (see Figure XV.2). The gas loading of the city gate is about 30%, which would allow extra gas use for construction. A refined petroleum pipeline is located about three miles to the southwest corner of the site, which could be used for shipment of FT diesel and other liquids. More studies are needed to evaluate this possibility.

XV.8 Labor force availability

A synfuel park located at Crane NSA would probably be able to draw much of its workforce from Crane and the surrounding communities. The workforce at Crane is highly skilled and some of those personnel could perhaps be shifted to activities associated with the synfuel park. In addition, Bloomington and Bedford are not too distant and could also contribute to the labor pool.

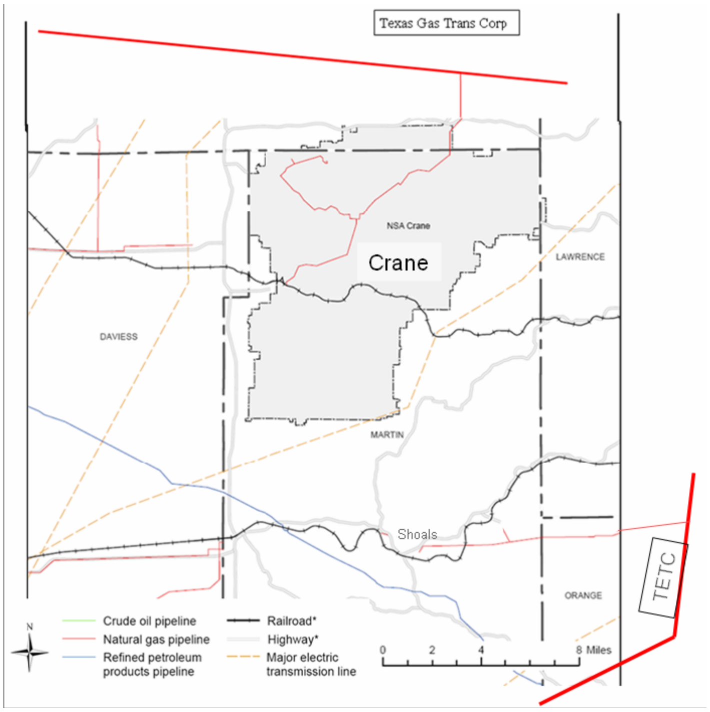


Figure XV.2. Transmission and gas pipeline systems around NSA Crane in Martin County (Irwin et al., 2007)

XV.9 Summary

NSA Crane has several advantages to recommend it as a site for a synfuel park. Land is plentiful, and the site is secure. In addition, because this land is on an existing military base, the environmental approval process would be expedited, meaning it would receive timely evaluation. The NSA Crane leadership has also expressed interest in the project and indicated that a lease arrangement could possibly be made for the land in return for energy services to be defined. Coal resources are reasonably close, and the infrastructure is generally good. The difficulties are that water availability must be enhanced by tapping either the East or West Fork of the White River and that transporting large equipment to Crane would be a challenge that could limit the economical scale of operation. In addition, some upgrading of the internal rail system may be needed to accommodate the flow of coal into the site. The economical scale of operation appears to be in the range of 20-40,000 tons of coal per day, with outputs of 10-20,000 bpd of FT liquids and 50-100 MW of power export. The prospects for SNG or hydrogen production will need to be evaluated jointly with the solution to the water supply issue.

XVI. NSA Crane in Sullivan

This site has an area of about 750 acres, including Lake Glendora. The lake is quite deep with a depth of over 120 feet in some places. Water area may be 30% of the complex (Figure XVI.1). Total water in the lake may be over one billion gallons and may be a good source of water for chemical processes as well as cooling. Strip mines are located off site in the nearby area. The site is also very close to Lake Sullivan, which has a water volume of about 2.5 billion gallons. About one fifth of the site is covered by water.

XVI.1 Coal availability

Coal is available near the Crane-Sullivan site. The Kindell #3 Penndiana Pit in Sullivan County is within 10-15 miles of the site and could supply adequate coal for a modest sized operation.

XVI.2 CO_2 sequestration potential

There are four potential options for geological sequestration of CO_2 from a gasification facility in the Crane-Sullivan area: enhanced coal bed methane production, enhanced oil recovery, enhanced shale gas production, and injection into deep saline water-filled aquifers. Detailed results of the quantitative assessment are presented in section E.4 of the appendix.

It appears that 132 million scf of enhanced coal bed methane could be produced with a potential storage of over 6 million metric tons of CO_2. Enhanced oil recovery has the potential to recover as much as 91 million standard barrels (stb) of crude oil and the potential to sequester 17 million tons of CO_2. Over 1.5 billion scf of enhanced shale gas could potentially be recovered with the flooding of about 0.6 billion tons of CO_2. Injection into deep saline water-filled aquifers has the potential for the sequestration of another 15.8 billion tons. Thus, there are several potential options for geological sequestration of CO_2 in the Crane-Sullivan area, with the greatest potential capacity in deep saline-filled aquifers and shale deposits.

XVI.3 Transportation infrastructure/logistics

Transportation infrastructure is required for: (1) shipment of large components of the synfuel plant, (2) the transportation of coal to the potential synfuel park, and (3) the distribution of finished products.

XVI.3.1 Shipment of large pieces of equipment to Crane-Sullivan

As indicated in section IV on regional transportation infrastructure, the likely mode of delivery for large equipment is to a port on the Ohio River with Evansville the most likely candidate due to its relative proximity to Crane-Sullivan. Once unloaded at Evansville, large equipment is best delivered via rail. There are at least 16 overpasses and bridges from Evansville to Sullivan. These impediments may limit the economical size of the synfuel park at Crane-Sullivan.

XVI.3.2 Transportation of coal to Crane-Sullivan

As noted in section XVI.1, Crane-Sullivan is reasonably close to coal mines. Coal could be delivered from the Kindill #3 mine via rail.

XVI.3.3 Transportation of finished products from Crane-Sullivan

Primary finished products of a synfuel park are likely to be FT diesel, gasoline, military fuel(s), naphtha, SNG and/or hydrogen. Sulfur is a byproduct that can be sold or given away for use in fertilizer production. These products can be shipped via rail. State highways can also be used for small quantities of product shipment.

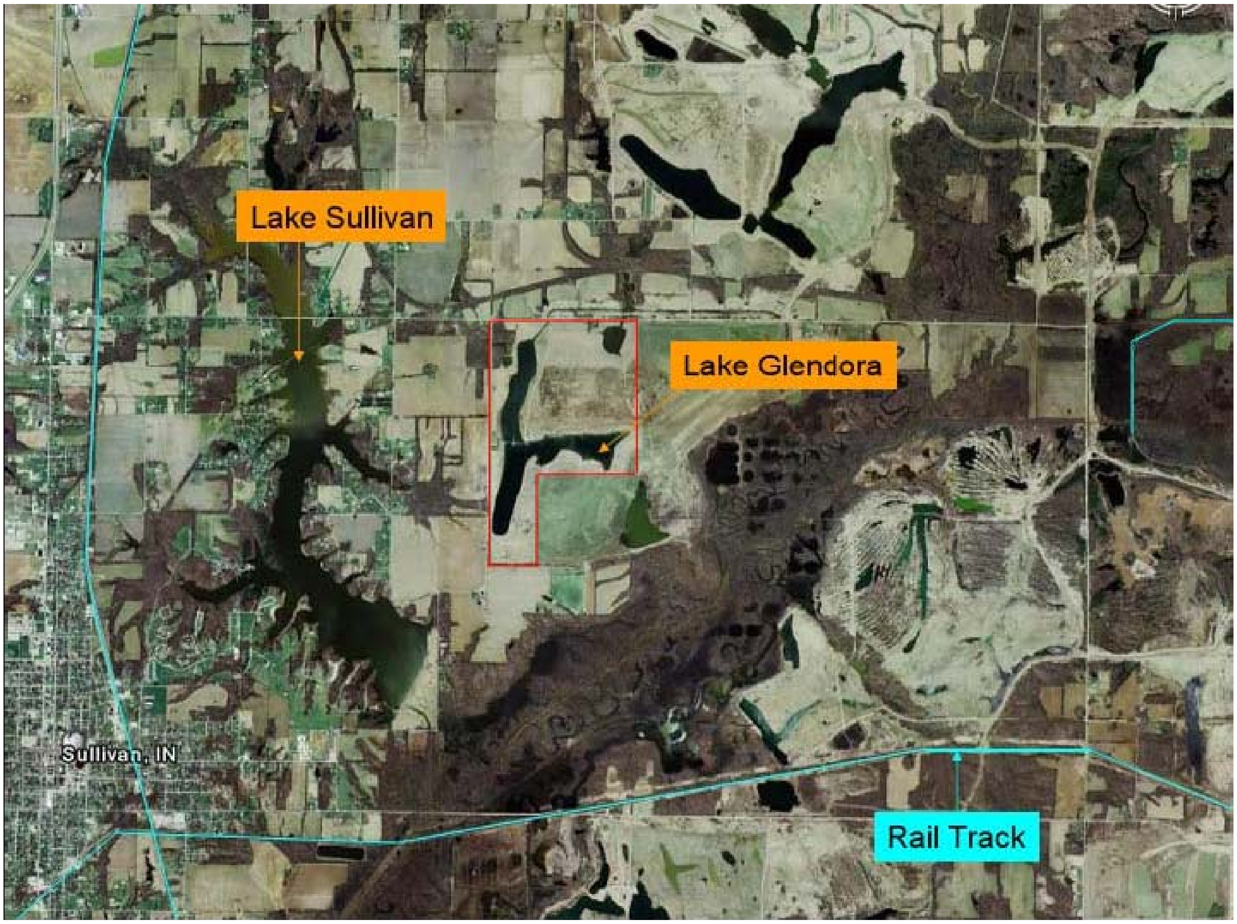


Figure XVI.1. Map of Crane Sullivan (Google Maps, 2007)

XVI.3.4 Transportation of slag/ash from Crane-Sullivan

Slag/ash can be trucked to a nearby location, such as mined-out strip mines in the area. There are several such sites scattered around the Crane-Sullivan region as shown in Figure XVI.1, and these may be economically attractive for slag/ash disposal.

XVI.4 Water requirements and resources

There is no major waterway nearby, and underground water resources are very limited. Therefore, a very large synfuel park/polygeneration plant may be infeasible using an all-wet cooling system and without getting water from a distance such as from the Wabash River, about 10 miles to the west. While the flow in the Wabash would be adequate to support a substantial synfuel park, the cost of a pipeline or canal would be considerable.

XVI.5 Land/ real estate requirements

Sufficient land is available on site for the main plant, coal handling facilities, etc. with the exclusion of land to dispose of slag/ash. However, as shown in Figure XVI.1, there are several mined-out strip mines in the area that could be used for slag/ash disposal.

XVI.6 Transmission lines and power availability

There is no power substation, and there are no significant transmission lines in the area. If power export were part of the output mix of the potential synfuel park, a substation and transmission lines would have to be built. This would represent a substantial cost.

XVI.7 Gas and oil pipelines

A gas pipeline runs fairly close to the site, and an oil pipeline is located less than ten miles north of the site. These could be extended to the Crane-Sullivan site at moderate cost. Pipelines for finished products could possibly be piggybacked on these other pipelines.

XVI.8 Labor force availability

A synfuel park at Crane-Sullivan would probably be unable to draw all of its labor force from Sullivan and the other small communities in the area. Some of the personnel would likely need to be sourced from Terre Haute, Vincennes and Bloomington.

XVI.9 Summary

The NSA Crane site at Sullivan is a fair candidate for developing a synfuel park. The primary advantages of this site are that adequate land is available (provided that land off site can be obtained at a reasonable cost for disposal of slag/ash), and that the land is part of a military installation making it a secure site and qualifying it for expedited evaluation of environmental approvals. The disadvantages are the limited availability of water (and thus the necessity of sourcing the water from the Wabash about 10 miles away) and the difficulty of transporting large equipment to the site. The economical scale of operation appears to be in the range of 20-40,000 tons of coal per day, with outputs of 10-20,000 bpd of FT liquids and 50-100 MW of power export. Given the challenges of obtaining adequate water resources, SNG or hydrogen production will need to be evaluated jointly with the solution to the water supply issue.

XVII. Other Potential Sites

Based on our detailed analysis of the preceding eight sites, we developed insight regarding the necessary features of advantageous sites for locating a synfuel park. These insights led us to enlarge our list of potential sites to include seven additional ones. The additional sites in southwest Indiana that may be good for hosting synfuel parks include:

1) One near the A.B. Brown Power Station,
2) One near the F.B. Culley Power Station,
3) One near the Rockport Power Station,
4) One near Tell City,
5) One in the Indiana Arsenal near Charlestown and Jeffersonville,
6) One near the Gibson Power Station, and
7) One near the Wabash IGCC Plant.

These sites are distributed along the Ohio and Wabash rivers. The sites along the Ohio River have the capability to receive very large equipment by barge. Distribution of finished products can also be achieved by barge. Rockport and Tell City are shown in Figure XVII.1, while A.B. Brown and F.B. Culley are shown in Figures XVII.2-3. The Indiana Arsenal (Figures XVII.4-6) is near Jeffersonville and the Jeffboat facility, which has the capability of handling large equipment. The potential synfuel park site near the Gibson power station on the Wabash River (Figure XVII.7) may also be able to use very large equipment because it can be barged to the site when the river is high during the wet season. The feasibility of delivering large equipment to the Wabash IGCC plant via barge is questionable and rail may be a better alternative.

Except for Jeffersonville, each of these sites is near one of the largest power stations in the State, which is advantageous for the development of a synfuel park with substantial power supply during construction and other infrastructure such as rail connection and other utilities. Coal supply is somewhat distant for the Rockport, Tell City and Jeffersonville sites via rail; however, this may not pose a serious problem if congestion on the rail system is not severe. Alternatively, coal may be barged to these sites along the Ohio River.

The advantages and disadvantages of the additional sites are summarized in Table XVII.1. The common characteristic of the sites is their easy access to water. With the possible exception of the Wabash IGCC site, they all have the ability to receive large equipment via barge. The latter is especially important because it allows the plant design to take advantage of the economies of scale in various components of the synfuel park.

The U.S. Military Reservation/Indiana Arsenal in Jeffersonville may deserve special attention. It has a very large land area, with rail routes running through many parts of the complex. The rail system in the complex is also connected to the CSX system (see Figures XVII.4-5).

Table XVII.1. Other potential sites in southwest Indiana

	A.B. Brown	**F.B. Culley**	**Gibson Power Plant**	**Jeffersonville/ New Albany**	**Rockport**	**Tell City**	**Wabash IGCC**
Coal availability	Coal by rail and/or barge	Coal by rail and/or barge	Gibson County Coal mine is a few miles away	Coal by rail and/or barge	Coal by rail and/or barge	Coal by rail and/or barge	Coal by rail and/or truck
CO_2 sequestration	ECBM EOR ESG Aquifer	ECBM EOR ESG Aquifer	ECBM EOR ESG Aquifer	Aquifer	ESG Aquifer	ESG Aquifer	ESG Aquifer EOR
Transportation of large equipment, and logistics	By the Ohio River and/or rail	By the Ohio River and/or rail	May be done via Wabash when water is high, or rail. Distribution of finished goods is very good	By Ohio River, excellent for large equipment. Distribution of finished goods is excellent	By Ohio River, excellent for large equipment. Distribution of finished goods is excellent	By Ohio River, excellent for large equipment. Distribution of finished goods is excellent	By rail
Land	Plenty of farm land	Plenty of farm land plus mined out areas	Plenty	Enough even after excluding the state park	Plenty	Plenty	Wooded area with pieces of flat land
Power transmission	Yes	Yes	Yes	Not far from substation	Yes	Yes	Yes
Gas pipeline	Local gas distribution pipelines nearby	About 4 miles from TGTC pipeline and the ANR pipeline	About 5 miles north of the TETC pipeline	About 6 miles north of the TGTC pipeline, plus local distribution	About 6 miles west of the MGT pipeline	About 6 miles east of the MGT pipeline	About 5 miles east of the MGT pipeline and 6 miles of the TGTC line
Water	Plenty	Plenty	Plenty	Plenty	Plenty	Plenty	
Environment, waste disposal	Can be done onsite	Near strip mines	Can be done onsite or nearby	Can be done onsite or nearby	Can be done onsite or nearby	Can be done onsite or nearby	

Figure XVII.1. Map showing A.B. Brown and its neighborhood (Google Maps, 2007)

Figure XVII.2. Map showing F.B. Culley and its neighborhood (Google Maps, 2007)

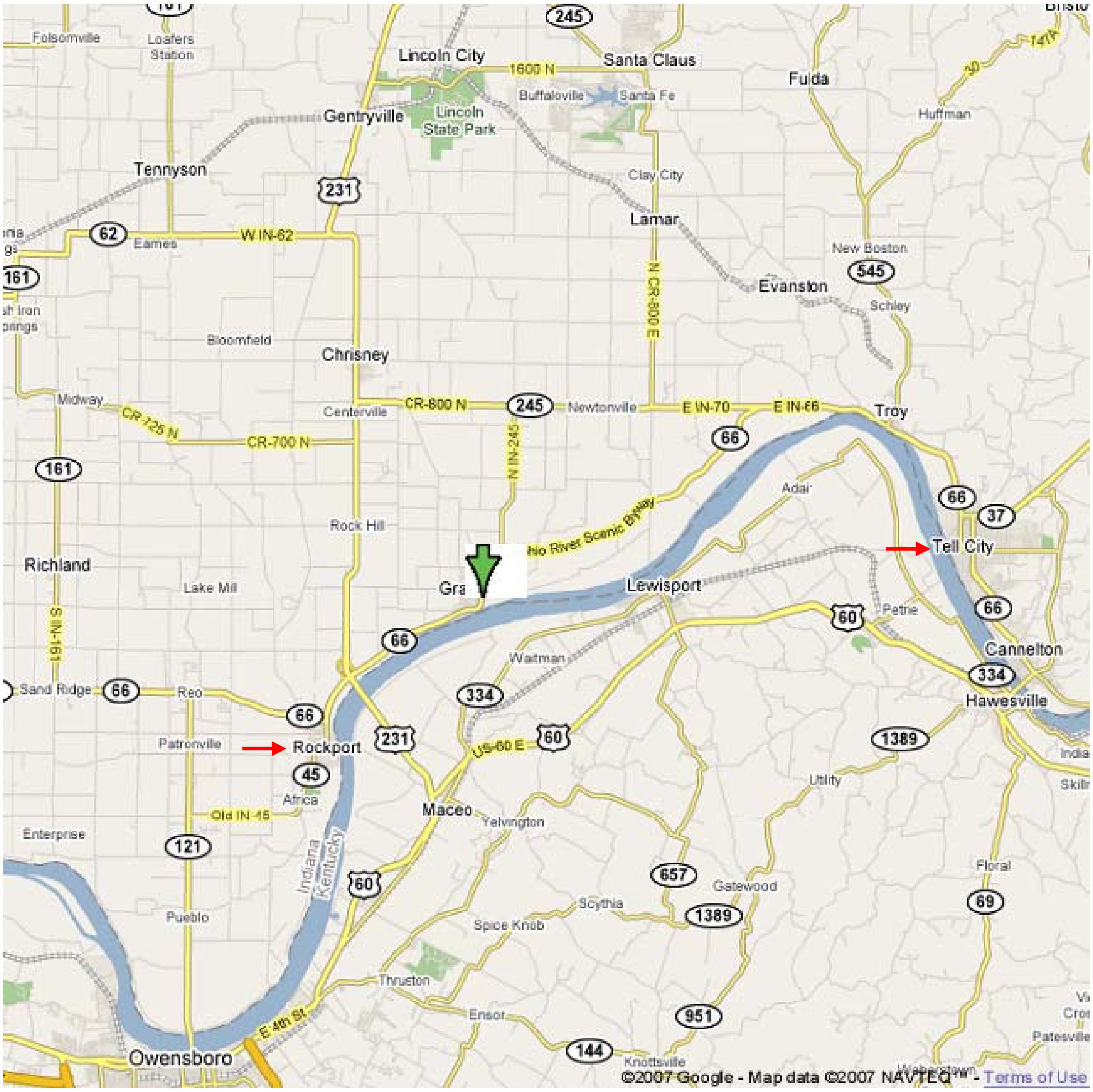


Figure XVII.3. The Rockport and Tell City region (Google Maps, 2007)
(An existing rail line from Gentryville to Rockport is not shown on this map)

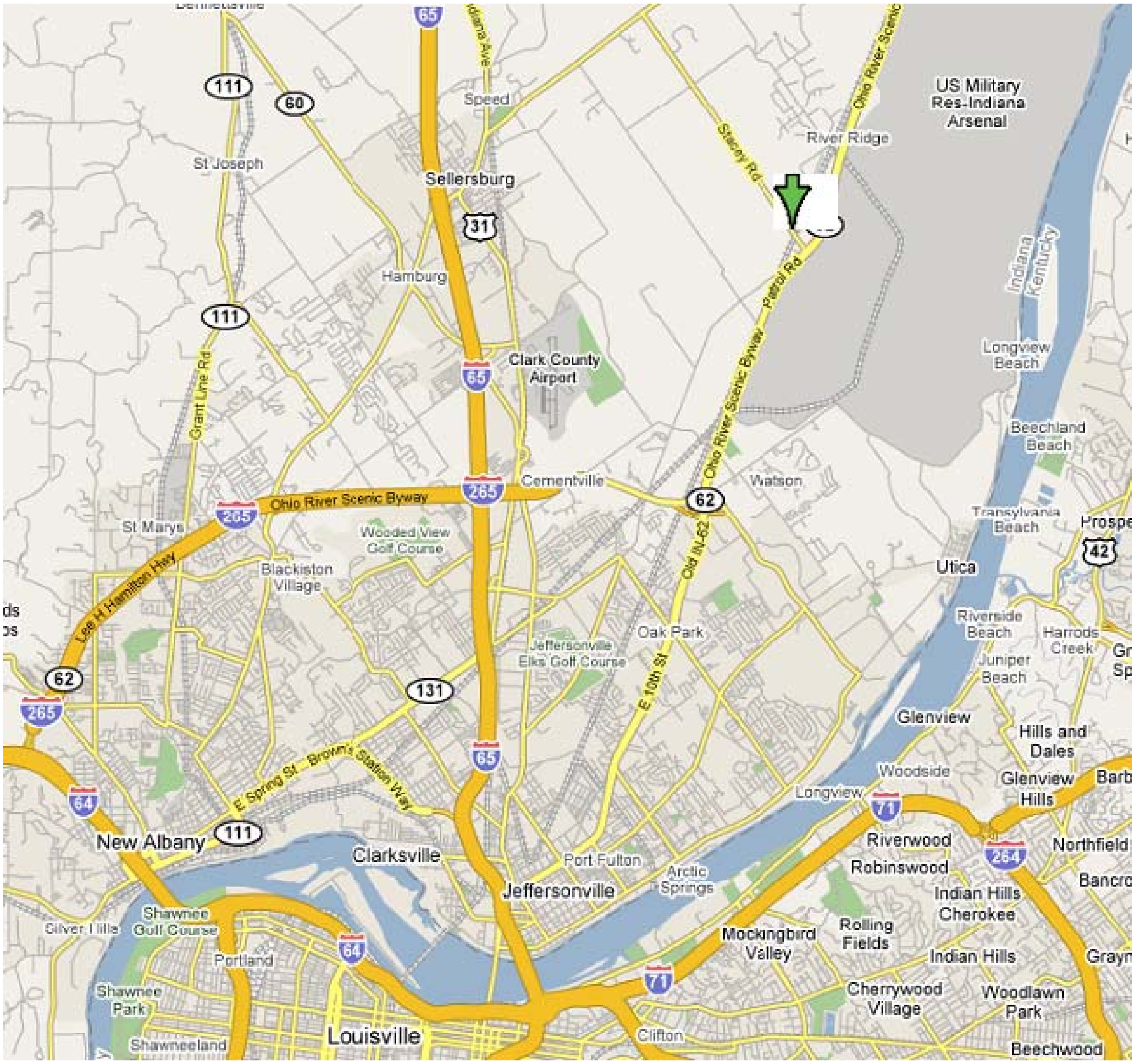


Figure XVII.4. Map of New Albany and the Indiana Arsenal (Google Maps, 2007)

Figure XVII.5. The lower section (closer to Jeffersonville) of the Indiana Arsenal (Google Maps, 2007)

Figure XVII.6. The upper section of the Indiana Arsenal (Google Maps, 2007)

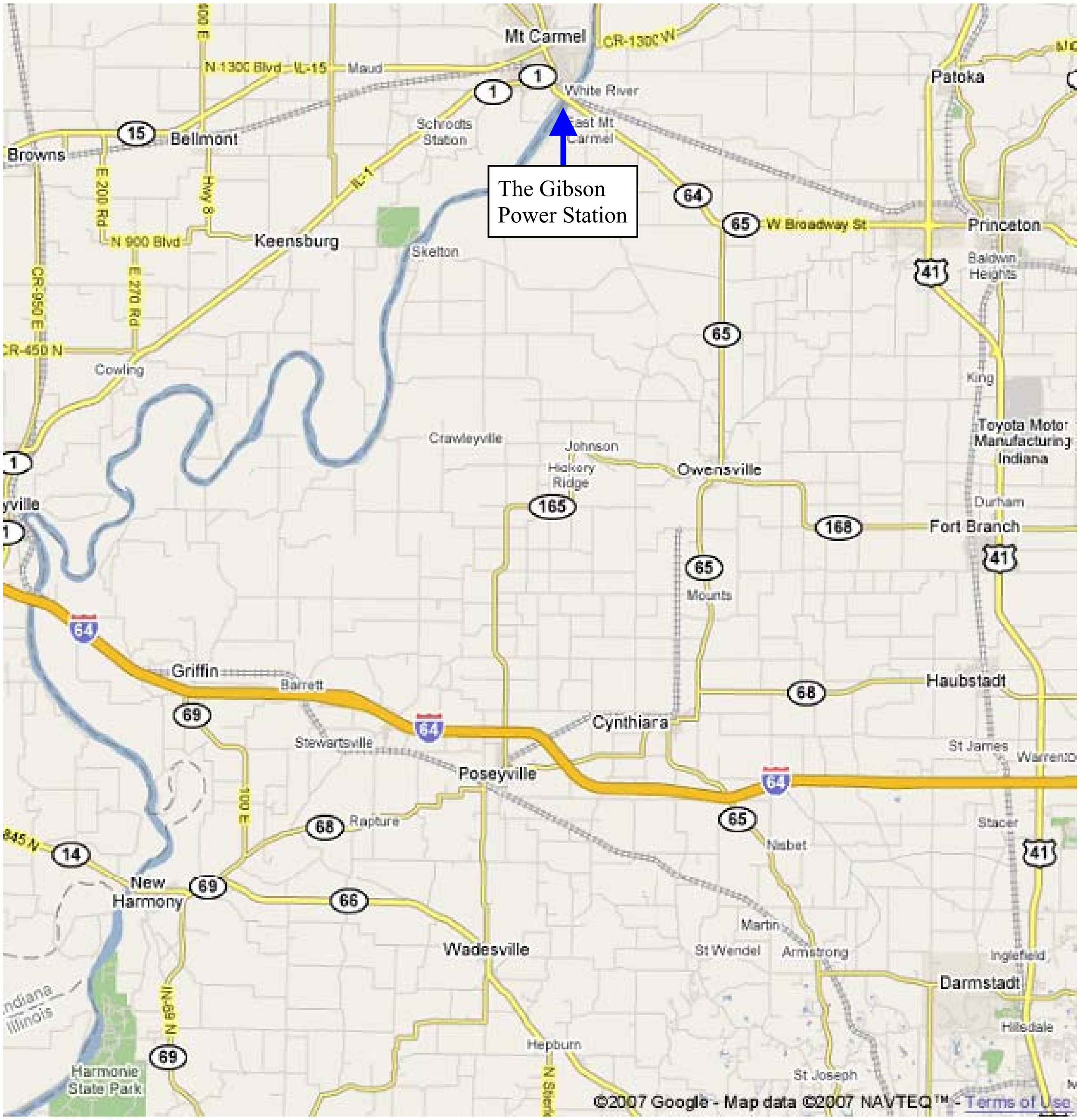


Figure XVII.7. Map of the Wabash River leading to the Gibson Power Station (Google Maps, 2007)

Figure XVII.8. Map showing the area of the Wabash IGCC Plant (Google)

XVIII. Policy and Regulatory Issues

In order to attract investment in synfuel parks in Indiana, several issues need to be addressed. First, changing regulations regarding the disposal of slag/ash could substantially lower the cost of land acquisition. Second, shortening the permitting processes would save developers substantial time and money. Both of these regulatory changes would help make Indiana a more competitive site for a synfuel park.

XVIII.1. Slag/ash disposal

Fly ash can be returned to strip mines if the amount is no more than 50% of the coal from the mine (Indiana Department of Environmental Management, 2007). As for underground mines, permits for sending fly ash to any underground mine can be requested, but the evaluation may be more stringent and time consuming.

However, there is currently no state policy governing slag disposal in underground mines. A policy allowing such disposal would obviate the need for developers to acquire additional land to dispose of slag/ash. Returning these products to the coal mines would also save transportation cost. If slag/ash must go to a land fill, then it must be sent there by truck or rail. If returning slag/ash to the mines is permitted, then railcars and/or trucks that would normally return to the mines empty could be used for hauling slag/ash back to the mines on return trips. Eliminating empty backhauls would greatly improve overall operational efficiency.

XVIII.2. Permits

Obtaining permits for a coal based synfuel park is expected to be time consuming, taking years from start to finish. In order to attract investment, it may be beneficial for the State to establish a system of fast tracking permits for projects that satisfy certain desirable criteria. Fast track permitting may reduce development time and cost.

XIX. Summary and Further Research

Several sites in southwest Indiana were evaluated as potential sites for synfuel parks. These preliminary feasibility assessments were used to identify the advantages and disadvantages of the different sites. Based on the analysis, all of the sites are feasible for the establishment of a synfuel park. However, they are not all equal. Some sites are suitable for larger or smaller operations, and the costs of construction and operation will vary substantially across sites.

What has become clear from the analysis is the following. In order to take advantage of economies of scale and to have maximum flexibility in the mix of outputs produced by the plant, it is important for the plant to be located on a body of water with substantial recharge – typically a major, navigable river. This location allows the delivery of large equipment and possibly coal, and for water to be used for processing and cooling. It is important that infrastructure (roads, rail, electric transmission network, and gas and refined petroleum product pipelines) be available to support both the construction and operation phases of the synfuel park. In addition, it is ideal for the area not to be too densely populated in order to facilitate the acquisition of land. Finally, it is important to have a means to sequester the CO_2 that will be emitted by the plant.

The primary focus of the project reported here has been the location of a synfuel park in southwestern Indiana. We focused primarily on coal to Fischer-Tropsch liquids as the primary type of plant, recognizing that the precise mix of liquids can be changed somewhat through plant design and that such a plant will typically have excess electricity generation capacity. In addition, we have also taken into account that by redirecting the syngas stream and including additional processing steps, it is possible to produce synthetic natural gas. Future work should recognize an even broader spectrum of uses for gasified coal, including methanol, fertilizers, and other chemicals.

There is a need to prioritize development efforts based on estimates of the benefits and costs of alternative types of plants. As noted in this study, some sites may be better suited for some mixes of products than others.

The Indiana State Utility Forecasting Group has been indicating a need to expand electric generating capacity for several years. There may be synergies to be obtained by thinking simultaneously about ways to develop clean coal transformation technology businesses within Indiana and to redesign the electric power supply system. One possibility is replacing or repowering existing generating facilities using substitute natural gas derived from coal. This approach would obviate the need to find new sites for power plants, which has become an increasingly thorny problem. As the repowering options are considered, priorities should be based on several factors. One consideration is power plant emissions, and one clear priority would be to focus repowering efforts on the "dirtiest" plants – unscrubbed coal-fired plants – first. Another consideration is the transmission and distribution network. If repowered capacity is to be expanded relative to existing capacity, it is critical either that the existing network can handle the increased load or that a simultaneous plan for network capacity expansion be implemented.

Understanding this part of the overall problem will require working closely with the State Utility Forecasting Group and the Midwest Independent Systems Operator.

A key part of clean coal technology is finding a way to deal with the CO_2 that is created by the conversion and combustion processes. A number of potential options have been addressed in this report, including sequestration in deep saline aquifers as well as options that produce revenue streams but may be less effective in sequestering, such as enhanced oil recovery, enhanced coal bed methane production, and enhanced shale gas production. Experiments such as FutureGen, and potentially other demonstration projects, will create important case study data regarding the feasibility and cost of these options. We will need to continue our collaboration with the Indiana Geological Survey to analyze these data to identify promising future strategies as Indiana develops its clean coal technology sector.

XX. References

Boardman, R. (2007, March). *Gasification and water.* Workshop presented at the Gasification Technology Conference, Denver, CO.

Brady, T. & Pfitzer, C. (2007, May). *A prescriptive analysis of the Indiana coal transportation infrastructure.* Available from http://www.purdue.edu/dp/energy/CCTR/

CEBX 800. (2006). http://southern.railfan.net/schnabel/cars/cebx800/cebx800.html

Chinchilla pilot burn project. (2007, September 28). http://www.lincenergy.com.au/cpb.html

Department of Energy. (2005, November). *Draft environmental impact statement for the Gilberton coal-to-clean fuels and power project* (DOE/EIS 0357). Gilberton, PA.

Department of Energy, Office of Fossil Energy. (2006, April). *Practical experience gained during the first twenty years of operation of the Great Plains gasification plant and implications for future projects.*

Department of Trade and Industry. (1999). *Coal Liquefaction – Technology Status Report.* Retrieved from The Department of Business Enterprise and Regulatory Reform website: http://www.berr.gov.uk/files/file18326.pdf

Drobniak, A., Mastalerz, M., & Shaffer, K. (2006, May). *Coal Supply and Demand in Indiana.(1st ed.).* http://www.purdue.edu/dp/energy/CCTR/

Environmental Protection Agency. (2007, October 1). *New Source Performance Standards, Subpart Da and Db—Summary of Public Comments and Response.* (EPA-453/R-98-005). http://www.epa.gov/ttncaaa1/t1/reports/nox-fdoc.pdf

Feldman, J. (2005). *When the Mississippi ran backwards*, New York: Free Press.

Foster Wheeler, Brook, P. (2005, July 12). *GTL – The Technical Challenges.* http://www.fwc.com/publications/tech_papers/files/GTL%20Challenges.pdf.

Ganter, E. (2005, September 21). *Commercialisation of Sasol's GTL technology.* Presented at Sasol Limited, UBS Global Oil & Gas Conference.

环球能源网 [Global Energy Network]. (2007, May 30). 国内首个气化采煤项目在内蒙古开建 [The first Chinese UCG polygeneration is under construction in Inner Mongolia]. http://www.in-en.com/coal/news/china/2007/05/INEN_96719.html

Google Earth. (2007, October). http://earth.google.com/

Google Maps. (2007, October). http://maps.google.com/

Hoosier Energy (2007, October), http://www.hepn.com/Merom.htm

Indiana Coal Council. (n.d.). *2006 Indiana coal Production.* Available from www.Indianacoal.com

Indiana Department of Environmental Management. (2007, June 27). *Utility rules workgroup – Indiana clean air interstate rule (CAIR) and Indiana mercury rule (CAMR).* http://www.in.gov/idem/programs/air/workgroups/mercury/

Indiana Department of Environmental Management. (2007, July 27), Memorandum 92-1, "Disposal of Coal Combustion Waste on Surface Coal Mines.

Indiana Department of Natural Resources, Division of Water. (2007, October 1). *Ground Water Assessment Maps and Publications (by county).* http://www.in.gov/dnr/water/ground_water/ground_water_assessment/GWAMaps.html

Indiana Geological Survey. (2007). http://igs.indiana.edu/

Irwin, M. W., Bowen, B. H., Preckel, P., Yu, Z., Rupp, J., Hieb, F. H., et al. (2007, May 31). *A feasibility study for the construction of a Fischer-Tropsch liquid fuels production plant with power co-production at NSA Crane.* West Lafayette, IN, Center for Coal Technology Research.

Jenkins, S. (2006, March). *Environmental permitting for IGCC power plants.* Presented at Gasification Technologies Council Workshop, Tampa, FL.

Louw, M. (2006, November 15). *CTL—GTL Sustainable Alternatives?.* Presented at Institute of Southeast Asian Studies Energy Forum, Singapore.

Lynch, T. (2005, December). *Clean coal and co-production potential.* Workshop presented at Purdue Clean Energy Conference. West Lafayette, IN.

Mastalerz, M. and Kvale, E.P., (2000). *Coal quality variation and coalbed gas content in boreholes SDH-383 and SDH-384 in Posey County, Indiana*. Indiana Geological Survey Open File Study 00-5.

NETL (2007), Carbon Sequestration Atlas of the United States and Canada: U.S. Department of Energy, Office of Fossil Energy, National Energy Technical Laboratory, Pittsburgh PA.

Olivier, M. (2007, July 19). Eskom studies 2,100 MW combined-cycle plant at Majuba. *Engineering News Online.* http://www.engineeringnews.co.za/article.php?a_id=111220

Perry, M., & Eliason, D. (2004, October). CO_2 *recovery and sequestration at Dakota Gasification Company.* Presented at conference of the Gasification Technologies Council, San Francisco.

Rentech Projects. (n.d.). http://www.rentechinc.com/rentech-projects.htm

Rardin, R., Yu, Z., Holland, F., Black, A., & Oberbeck, J. (2006, June). *CO_2 Capture Cost Estimates from a State Perspective.* Proceedings from Institute of Electrical and Electronics Engineers Power Engineering Society General Meeting, San Francisco.

Rardin, R., Yu, Z., Holland, F., Black, T., & Oberbeck, J. (2005, December). *Factors that affect the design and implementation of clean coal technologies.* West Lafayette, IN: Purdue Energy Model Research Groups.

Sasol outlines its process for Fischer-Tropsch US military fuel. (2007, April 23). *Green Car Congress.* http://www.greencarcongress.com/coaltoliquids_ctl/index.html

SES and Golden Concord to build coal gasification, methanol and DME plant in China. (2007, June 6). *Green Car Congress.* http://www.greencarcongress.com/dme/index.html

Sharp, C.R., Kubek, D.J., Kuper, D.E., Clark, M.E., & DiDio, M. (2002, April). *Recent Selexol operating experience including* CO_2 *capture.* Paper Presented at the Fifth European Gasification Conference, Noordwijk, The Netherlands.

U.S. Army Corps of Engineers. (n.d.). *National waterway network.* http://www.iwr.usace.army.mil/NDC/gis/ddgis.htm

U.S. Department of the Interior, U.S. Geological Survey. (2006). *Water Resources in Indiana.* http://in.water.usgs.gov/nwis-index.shtml

Van Bibber, L., Shuster, E., Haslbeck, J., Rutkowski, M., Olson, S., & Kramer, S. (2007, April). *Baseline technical and economic assessment of a commercial scale Fischer-Tropsch liquids facility* (DOE/NETL-2007/1260). Department of Energy, National Energy Technology Laboratory.

Welcome to IDEM. (n.d.). http://www.in.gov/idem/

Yu, Z., Black, T., & Rardin, R. (2005, June). The Role of IGCC in the Global Energy Markets: Part I: Technology Progress and Applications. In *Proceedings from Institute of Electrical and Electronics Engineers Power Engineering Society 2005.* San Francisco: Institute of Electrical and Electronics Engineers Power Engineering Society.

APPENDICES

Appendices A through E are available on the CCTR website at:

http://www.purdue.edu/dp/energy/CCTR/researchReports.php

If you would like a bound hard copy of these appendices, please send your request to:

CCTR/Energy Center
Purdue University
500 Central Drive
West Lafayette IN 47907-2022 USA
Email: cctr@ecn.purdue.edu