Scoping Study

Development of Coking/Coal Gasification Concept to Use Indiana Coal for the Production of Metallurgical Coke and Bulk Electric Power

Final Report

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Table of Contents

Executive Summary

Although coke is an absolutely essential part of iron making and foundry processes, currently there is a shortfall of 5.50 million tons of coke per year in the United States. The current shortfall of this critical raw material is being filled by imports, mainly from China and, to a lesser extent, from Japan. The result of the shortfall internationally has been that recent coke prices have risen sharply. For example, coke delivered FOB to a Chinese port in January 2004 was priced at $60/ton, but rose to $420/ton in March 2004 and in September 2004 was $220/ton. This makes clear the likelihood that prices will remain high with considerable volatility.

The significant shortfall of needed coke has placed an enormous strain on Indiana's steel industries. A resolution and/or mitigation of this formidable problem through the use of Indiana coal in a mine mouth, environmentally friendly, high efficiency coking/coal gasification facility which would increase coke supply and production, while, at the same time, reducing the cost for Indiana's steel and foundry industry. In addition, such a high efficiency coking facility would produce electricity for sale to the wholesale electric market, thereby reducing costs and environmental emissions and, at the same time, enhancing electric system reliability.

Expansion of the capability to produce coke is being planned by Indiana's steel industry and at present essentially all of the coal used in the coking process is imported from outside Indiana. This report addresses a new concept for producing coke that would use Indiana coal as the main feed stock.

Indiana is home to roughly 22% of the domestic base steel production for the United States. One essential raw material needed by this industry is coke. Current 2005 forecasts indicate that the United States will produce 11,500,000 net tons of coke, but will require 17,000,000 net tons for blast furnace, foundry, and related uses.[1] At present, essentially no Indiana coal is being used for coke production. In 2002, Indiana's steel industry used an estimated 10.7 million tons of coal. Of this, approximately 8.1 million tons was used for coke production.[2] Most of this coking coal comes from West Virginia and Virginia.

Recently it has been reported that a subsidiary of the Russian steel giant, OAO Severstal plans to invest $140M to rebuild aging coke ovens at the Wheeling-Pittsburgh Steel Corporation's Follansbee site.[3] After the renovation, Severstal plans to retain 50% of the coke output for their use. Such an investment by an international steel producer is an indication of the crucial nature of coke for the steel industry. The proposed research provides a path for Indiana coal to be an active participant in this highly profitable expanding market. The approach will involve not the rebuilding of an aged technology, but the development and utilization of a cutting-edge technology that will be especially relevant for the future of the industry.

This report details the results of a scoping study that conceptually evaluates the feasibility of developing a mine mouth coking/coal gasification concept that uses Indiana coal. The general conclusion of this study is that there is significant potential to use Indiana coal for the purpose of producing coke for use in various industrial applications. In addition, there is also meaningful potential to also use gas produced in the coking process for a variety of purposes including electric generation.

The next steps in the this effort entail development of computer and process models for detailed evaluation of the value of Indiana coal in coking processes as well as initial processes designs for coking, gasification, and liquid fuel production. This effort would require one year at a funding level of $100,000. Following the initial modeling effort, it is proposed that more detailed modeling and laboratory tests be conducted to further validate and develop the proposed processes. This effort would be done in conjunction with either or both an existing or planned coke production facility. It is estimated that the testing and process development effort would require initial funding of $600,000 over a two year period. Funding will be leveraged and additional funding would be pursued from Federal, State, and industry sources for the development of a demonstration project.

List of Figures

List of Tables

Introduction

A viable supply of iron is one mainstay of economies throughout the world. Issues associated with the supply and price of iron, which is used to produce steel, play either a direct or indirect role in all modern business operations. Indiana is home to approximately 22% of the base steel production for the United States and consequently there is enormous incentive to assure the supply, quality, and price of the raw materials that are used in its production. One of the major components used in the iron making process is coke.

Coke is a solid carbon fuel and carbon source used to melt and reduce iron ore. Coke production begins with pulverized, bituminous coal. In current operations, coal itself can not be used in place of the central placement of coke in a blast furnace because it would not form a permeable bed of sufficient strength and porosity to support the weight of material in the blast furnace.

Coal is fed into a coke oven which is sealed and heated for 14 to 36 hours to about 1100 C (2000 F). Coke is produced by heating particulate coals of very specific properties in a refractory oven in the absence of oxygen (or with limited oxygen at the top of the coal bed in the case of non recovery coke ovens). As temperature increases inside the coal mass, it melts or becomes plastic, fusing together as devolatilization occurs, and ultimately resolidifies and condenses into particles large enough for blast furnace use. During this process, much of the hydrogen, oxygen, nitrogen, and sulfur are released as volatile by-products, leaving behind a partially crystalline and porous carbon product. The quality and properties of the resulting coke is inherited from the selected coals, as well as how they are handled and carbonized in coke plant operations.

Heat is often transferred from one coke oven to another to reduce energy requirements. After the coke is finished, it is moved to a quenching tower where it is cooled with a water spray. Once cooled, the coke is moved directly to an iron melting furnace or into storage for future use. Currently essentially no Indiana coal is used to produce coke.

Coke production is traditionally one of the major pollution sources from steel production. At present there are two main methods of producing coke. First, a recovery process in which the coal is heated in a completely reducing atmosphere and the volatile products are recovered in an associated chemical processing plant. Major issues associated with this process include the complexity of the chemical processing and the production of potentially hazardous compounds. There is also a major concern with the tar that is left after processing. This material is also potentially hazardous and is generally stored on site and thus presents a significant future disposal concern. The complexity of the chemical processing introduces added cost and process operational details that have restricted the use of this option in the past for coking and simultaneous power production.

Air emissions such as coke oven gas, naphthalene, ammonium compounds, crude light oil, sulfur, and coke dust are released from many coke ovens. Emissions control equipment can be used to capture some of the gases and heat can be captured for reuse in other heating processes. But, traditionally, some gases escape into the atmosphere as the coke oven ages. Air and water emissions from coke production can be reduced by using a non-recovery coke battery. In traditional plants, by-products are can be recovered. In non-recovery batteries, pollutants are combusted in the coke oven itself, which is often maintained at a negative pressure. This technique consumes the by-products, eliminating much of the air and water pollution.

In the non recovery process air is introduced above the top of the coke bed in the oven and the volatiles are combusted. The Environmental Protection Agency has stated that new ovens must meet non recovery standards. The hot gases from the oven can then be used in a heat recovery boiler to produce steam and subsequently generate electricity. Relatively small amounts of hydrogen are produced in this process and are recalculated to the bottom of the furnace to provide heat for the process. Figure 1 depicts coke at the conclusion of the coking process in a conventional slot oven.[4] Figure 2 depicts the coke after it has been pushed from a slot oven.[5] Figure 3 depicts a non recovery coke oven.[6]

Figure 1: Coke in a Slot Coking Oven

Figure 2: Coke from Slot Oven

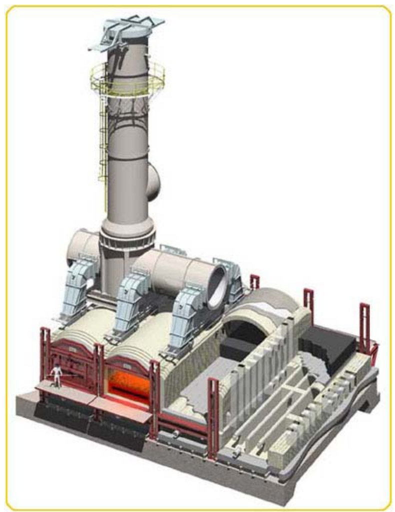


Figure 3: Non Recovery Coke Oven

In the iron making process, iron ore, coke, heated air and limestone or other fluxes are fed into a blast furnace. The heated air causes the coke to combust, which provides the heat and carbon sources for iron production. Limestone or other fluxes may be added to react with and remove the acidic impurities from the molten iron in the form of slag. A typical blast furnace operation indicating the location of the coke is depicted in Figure 4.[7]

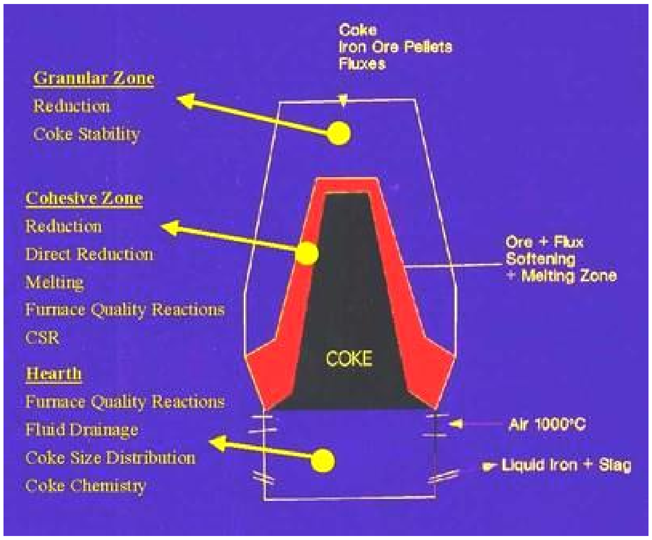


Figure 4: Typical Blast Furnace Zones

One key issue in blast furnace iron making is the strength of the coke. The coke produced from Indiana coal has less strength than coke produced from current metallurgical coal sources and consequently is smaller in size. This means that it will be used in upper portions of the blast furnace. Typical characteristics of coke used in blast furnace operations is shown in Table 1.[8]

Physical: (measured at the blast furnace)	**Mean**	**Range**
Average Coke Size (mm)	52	45-60
Plus 4” (% by weight)	1	4 max
Minus 1”(% by weight)	8	11 max
Stability	60	58 min
CSR	65	61 min
Physical: (% by weight)		
Ash	8.0	9.0 max
Moisture	2.5	5.0 max
Sulfur	0.65	0.82 max
Volatile Matter	0.5	1.5 max
Alkali (K_2O+Na_2O)	0.25	0.40 max
Phosphorus	0.02	0.33 max

Table 1: Typical Blast Furnace Coke Characteristics

This report details research that was conducted from March 1, 2005 to the present to determine the viability of using Indiana coal for the production of coke. Specifically, the concept of locating a modified non recovery coking facility at a mine in Indiana with energy recovery for the generation of electricity was considered. In addition, extension of the technology to include gasification and local power production were also considered. The results of this study indicate that there is a high potential to use Indiana coal for coking as well as other industrial purposes both within and outside Indiana. A flow diagram of the initial study concept is depicted in Figure 5.

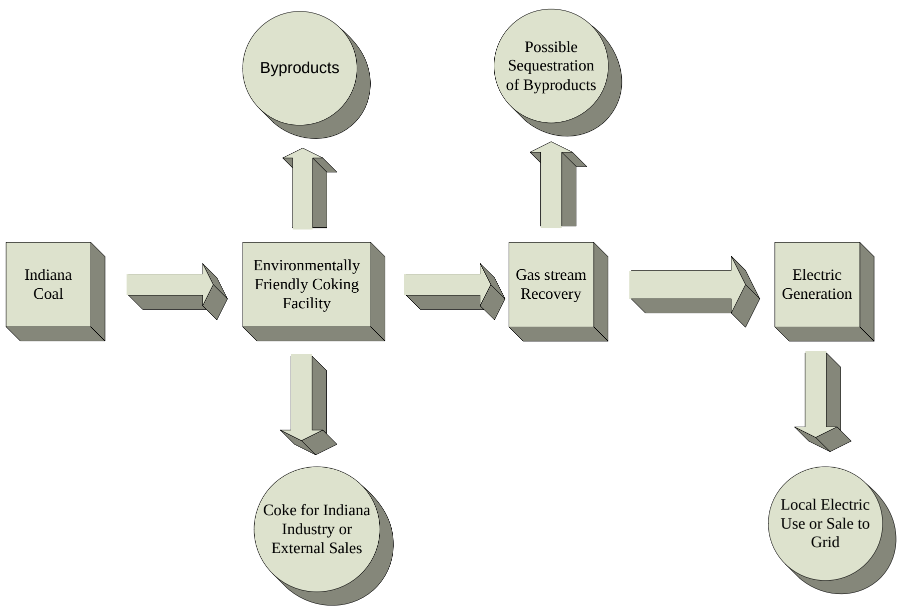


Figure 5: Initial Concept Description

The coal used for the proposed coking process would be a mix of Indiana Brazil Seam or potentially other Indiana coals, as previously identified by the Indiana Geological Survey, blended with other coals to meet metallurgical and emissions requirements. Currently this approach has been used successfully to dramatically increase coke quality.

The coke produced from Indiana coal has less strength than coke produced from conventional metallurgical coal and this results in coke sizes that fall into two general classes. One class, often referred to as Buckwheat or Nut coke, is on the order of 1 inch x ¼ inch as compared to conventional blast furnace coke which is on the order of 1 inch x 4 inches. The other class is called coke breeze and is much finer. It is used as a source of carbon in steel making, for palletizing, sintering, as well as in the elemental production of phosphorous. It can also be made into briquettes and used to feed blast furnaces in combination with iron ore pellets. Other industries that use coke breeze include cement, paper, fertilizer, as well as others. Buckwheat/Nut coke is classically used in the steel industry as a carbon source for electric furnaces, in the production of ferromagnesium and ferrosilicon products, and in the production of elemental phosphorous.

An investigation of ways to increase the use of coke produced from Indiana coal in various industrial processes is under way. One effort preliminarily considered concepts for how current Computational Fluid Dynamic Research efforts for blast furnace hearth modeling could be extended to increase the use of coke produced from Indiana coal in the steel making process. Computational fluid dynamics (CFD) simulation has become a cost-effective tool that can provide detailed information on flow properties and that can be used to conduct extensive computer experiments for design and optimization of flow systems. Several steel manufacturers have expressed interest in considering how Indiana coal might be used for various production processes. They also indicate that they have considered and/or are currently considering using Indiana Coal usually at low levels in blends. A formal CFD coke research effort could significantly extend this use.

Research efforts regarding blast furnace Computational Fluid Dynamics (CFD) at Purdue University Calumet, currently funded by the 21st Century Fund at $1.29 million, will be leveraged to provide additional support for this proposal. Preliminary concepts for the inclusion of CFD technology in mine mouth coking processes, as well as the use of the produced coke in blast furnace operations, will be considered. Due to the physical characteristics of Indiana coal[9], the coke produced will tend to be of a smaller size, but there are many opportunities to use this type of coke in blast furnace and other operations. The use of CFD analysis will assist in maximizing the applicability and value of coke generated from Indiana coal.

It is proposed that CFD studies be used in the next stage of the developmental activities as part of efforts to increase the percentage of Indiana coal used in the proposed technology. It is anticipated that such a study would develop a preliminary computational fluid dynamics (CFD) model to analyze and predict thermal, chemical, and physical phenomena for optimizing the coke/gasification process. The CFD simulations would be used to (1) provide fundamental insights of the process (2) investigate the impact of key operation and design parameters on process performance and (3) scale-up and optimize the process.

As part of the process developmental effort, various analyses will be required for different samples of Indiana coal that are determined to be candidates for use in coking applications. The list of tests that have been identified for this characterization is depicted in Table 2. The complete scope of testing will be defined as part of the preliminary process modeling effort.

I. Proximate Analysis
   a. Moisture
   b. Volatile matter
   c. Fixed carbon
   d. Ash
   e. Sulfur
   f. BTU/lb (heating value)
   g. Free swelling index

II. Ultimate Analysis
   a. Carbon
   b. Hydrogen
   c. Nitrogen
   d. Oxygen
   e. Chlorine

III. Ash Chemistry
   a. SiO_2
   b. AL_2O_3
   c. Fe_2O_3
   d. CO
   e. MgO
   f. K_2O
   g. P_2O_5
   h. Na_2O

IV. Rheological Properties
   a. Gieseler Plastometry (fluid characteristics)
   b. expansion and contraction
   c. Sole heat oven test (SHO)

V. Petrographic Tests
   a. Petrographic composition of coal
   b. Rank determination by reflectance
   c. Fluorescence analysis

Table 2: Future Coal Tests

Two examples of coke quality produced via pilot oven carbonization using Indiana coal are given in the Table 3:

	100% Indiana (Brazil Block Coal)	100% Indiana (Danville, No. 7 coal)
Coke Stability	33	33
Coke Hardness	54	69
CSR*	48	30
Coke size, mm	53	55
Coke yield, %	67.9	67.0
Coking Time, hr	18.6	20.15
Max. Pressure, kpa**	2.07	2.96

(Note: CSR*=Coke strength after reaction with CO2, Max Pressure** = maximum oven wall pressure)

Table 3. Examples of Coke Quality

A metallurgically compatible sample of Indiana Brazil seam coal was obtained from Solar Sources. This coal was analyzed by the coke laboratory at US Steel in Gary, Indiana. Results of this analysis are shown in Table 4.* As can be observed from the data in this table, this particular coal when blended with other metallurgic coal would be suitable for blast furnace coking purposes. An example of three types of coal blends used by the Japanese Steel Industry in 1975 for coke production is depicted in Figure 6.[10]

* The assistance of Solar Sources in obtaining the sample and US Steel in performing the analysis was extremely helpful to this effort and is greatly appreciated.

Purdue Coal Sample 7-20-2005	%
Moisture Content	2.38
Size Analysis	
+ 1- ¼ "	8.8
+ 1"	15.8
+ ¾"	25.9
+ ½ "	40.1
+ ¼ "	59.6
+ 1/8 "	12.9
Mean size	1.44
Proximate Analysis	
Volatile Matter	37.08
Fixed Carbon	53.62
Ash	9.30
Sulfur Content, % Dry	0.76
Oxidation Test (% Trans.)	97.0
Petrographic Analysis	
V-Types	
3	0.4
4	11.5
5	55.0
6	33.0
7	0.1
RO	0.57

Table 4: Indiana Coal Test Results

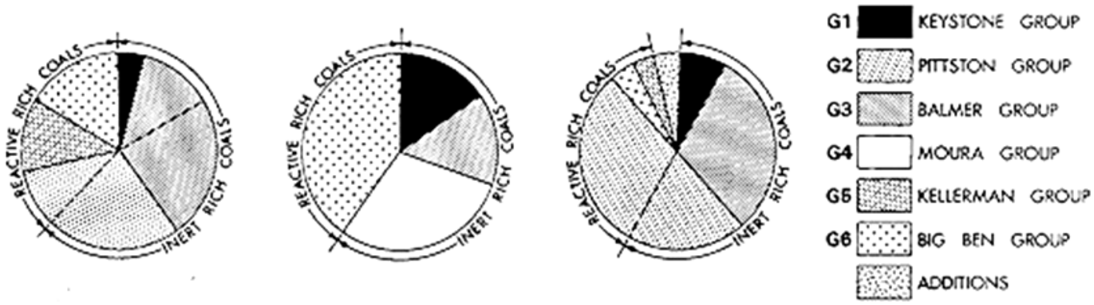


Figure 6: Coking Coal Blend Example

One way to rank coals is by the amount of volatile matter they contain. At the simplest level, mid-range prime coking coals will produce the best coke and the farther a particular coal is away from prime coking coal, the less suitable it is. Coke from high volatile coals tends to be too weak and reactive to be used in the blast furnace. Also, carbonizing low volatile coals can produce unacceptably high pressures on oven walls for slot ovens.

When coal is viewed under a microscope, it can be seen to be composed of three main components, or macerals, analogous to the minerals found in rocks.[11] The first of these, vitrinite, softens on heating. It in association with the other components, liptinite and inertinite, forms the coke matrix. These components reflect light at different intensities. In general, the reflectance of the vitrinite is a measure of the rank of the coal and is inversely proportional to the volatile matter content. Ususally a coal blend for blast furnace coke should have a reflectance between 1.25% and 1.35%. The reflectance of coals blends tends to vary linearly, but having the average reflectance of a blend in this range is not sufficient to assure that the produced coke will have the desired qualities. For this reason the reflectance distribution is considered.

If the reflectance values from a sample are plotted in a histogram, it is desirable to have a distribution that resembles a normal distribution with not too large a standard deviation. Unacceptable distributions have large standard deviations or have multiple peaks.[12] Attempts at using simple linear programming models to determine coal blends for coking have produced varying results due to the complexity of the coking process.[13] Modeling must also consider other characteristics such as dilatation and fluidity, which provide empirical measures of the extent of softening and fusion on heating, in the blending process.

Concerns with the relative strength of the coke produced from Indiana coal can be reduced by carefully blending various types of coal. Through blending many potential issues with coke characteristics can be reduced or eliminated. Classically, coal blending for coke production has been considered to contain a level of “art” to the process. The research team for the proposed project has had considerable experience in customizing coal blends used for coking processes in operating industrial coke production facilities. This experience will be a valuable attribute in customizing the process to maximize the use of Indiana coal. The research team will develop blending models and/or recommendations that will help to increase the use of Indiana coal for industrial purposes. The nature of the coal blend for the current proposal would be a function of the coking process detail and will require additional research to determine the optimal values.

The current research has also considered if it would be conceptually possible to modify the mass balance in the coking process in a way that would allow for a usable level of gas production that could be used to power a combustion turbine for electric production. In discussions with various operational, research, and engineering personnel it has been found that there is a possibility that a portion of the pyrolysis gas could be extracted from the gas stream as it is recirculated to the floor of a non recovery coke oven also referred to as the sole plate. The degree of gasification and influence on operations would need to be considered in a subsequent detailed study. Figure 6 shows the gas recirculation down comers in one non recovery design.[14]

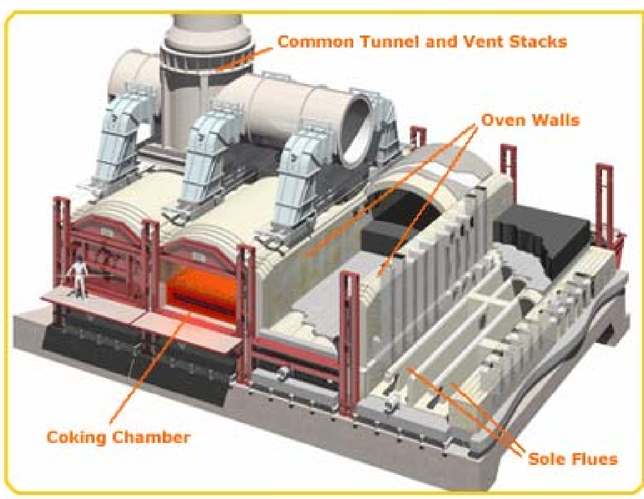


Figure 7: Sole Flue Orientation

Various industry contacts were established to obtain background for the project. Two coal mines were contacted and a coal sample was obtained. One mine has indicated an interest in considering the concept for a mine mouth coking facility. Preliminary discussions have considered how such a facility might be developed. Two steel mills were visited and process applications of Indiana coal were discussed. One of the steel mills performed analysis of a sample of Brazil Seam Coal. A coke production facility was visited and issues regarding coking technology were considered.

Four visits to Argonne National Laboratory were made to discuss various aspects of the proposal. Specifically there was discussion regarding the possibility for partial gasification. Argonne currently uses the Aspen model for much of its coal gasification modeling.[15] Should additional funding become available it may be possible to arrange for scoping studies to be conducted using the Aspen model. Access to the Aspen model licensed to Purdue University is currently being obtained. Efforts to use Aspen for coking operation modeling will also be pursued at Purdue University Calumet should additional funding become available.

Another process modeling tool, Metsim, was obtained and is currently being used to consider initial design concepts.[16] Metsim is a computer program that can model industrial processes, unit operations, and chemical and metallurgical processes. During an initial training session for Metsim, its developer offered to supply a previously developed Metsim model of the pyrolysis process during coking. This model will be useful for considering preliminary details of extracting coke oven gas streams.

The proposed coke production process would take place near or at an Indiana coal mine and, hence, would afford a transportation savings because a large portion of coal used by the coking facility would not have to be transported over a long distance. At times transportation costs have approached the cost of the coal itself. The total transportation cost would be reduced, since the mass of the product coke is less than the coal needed to produce it and also because coke is less dense than coal. Thus, a significant cost savings from the reduced weight per mile of material being transported would result. Moreover, there may be an opportunity to consider the value of some emissions credits, due to the “clean coal technology” as well as the different geographic location. Preliminary discussions regarding transportation have occurred, but more detailed discussion is awaiting more information as to possible facility site locations.

A coking/coal gasification process would be used that would produce metallurgical grade coke using a significant percentage of Indiana coal and, at the same time, would produce a byproduct gas stream that would be usable in a cogeneration facility for the production of electricity to be sold in the electric market. Initial power flow studies have been investigated to determine the potential value of the generated electricity. Alternatives for electric production including heat recovery and potentially partial coal gasification were also evaluated. Results indicate that electric production in conjunction with coke production provides a significant economic benefit. Issues of the ability to produce electric ancillary services as part of the operation are also being considered.

With a mine mouth operation, blending and storage of coal feed streams would be done on site and would thus allow for scheduling the production of electricity to correlate with times of high market value. Further discussions of this topic are awaiting more information on possible site locations.

In the performance of the initial scoping study, it was also been determined that there is a significant possibility to use existing or new coking facilities as a source of pyrolysis gas for the production of liquid transportation fuels through a Fischer-Tropsch process. In this approach, existing or planned coke production facilities would be used as part of the developmental process thereby reducing the process development risk as compared to construction of a dedicated test facility. This proposal is based upon a design in which the risk and financing level required for development of an operating facility is reduced by developing the technology in conjunction with an operating or planned coking facility. The value of products, including liquid fuels, would be evaluated in comparison with conventional coke production operation. The amount of such products produced would be determined by optimizing the value of the various product streams. The process would adapt itself to changing market conditions. This would reduce the risk of developing new liquid fuel production capability since the major capital expenditure will be justified for conventional coke production. This concept is depicted in Figure 8. Further research is required to determine the conceptual details, feasibility of individual processes, and design recommendations.

A concept for a process for the sequestration of the carbon dioxide produced by the process was also identified. Preliminary investigations indicate that it may be possible to produce a usable chemical product as part of the carbon dioxide sequestration process by the use of a nano catalysist. A concept for using a nano catalysist to enhance the coke oven gas based Fischer-Tropsch process for the production of liquid transportation fuels is also being considered.

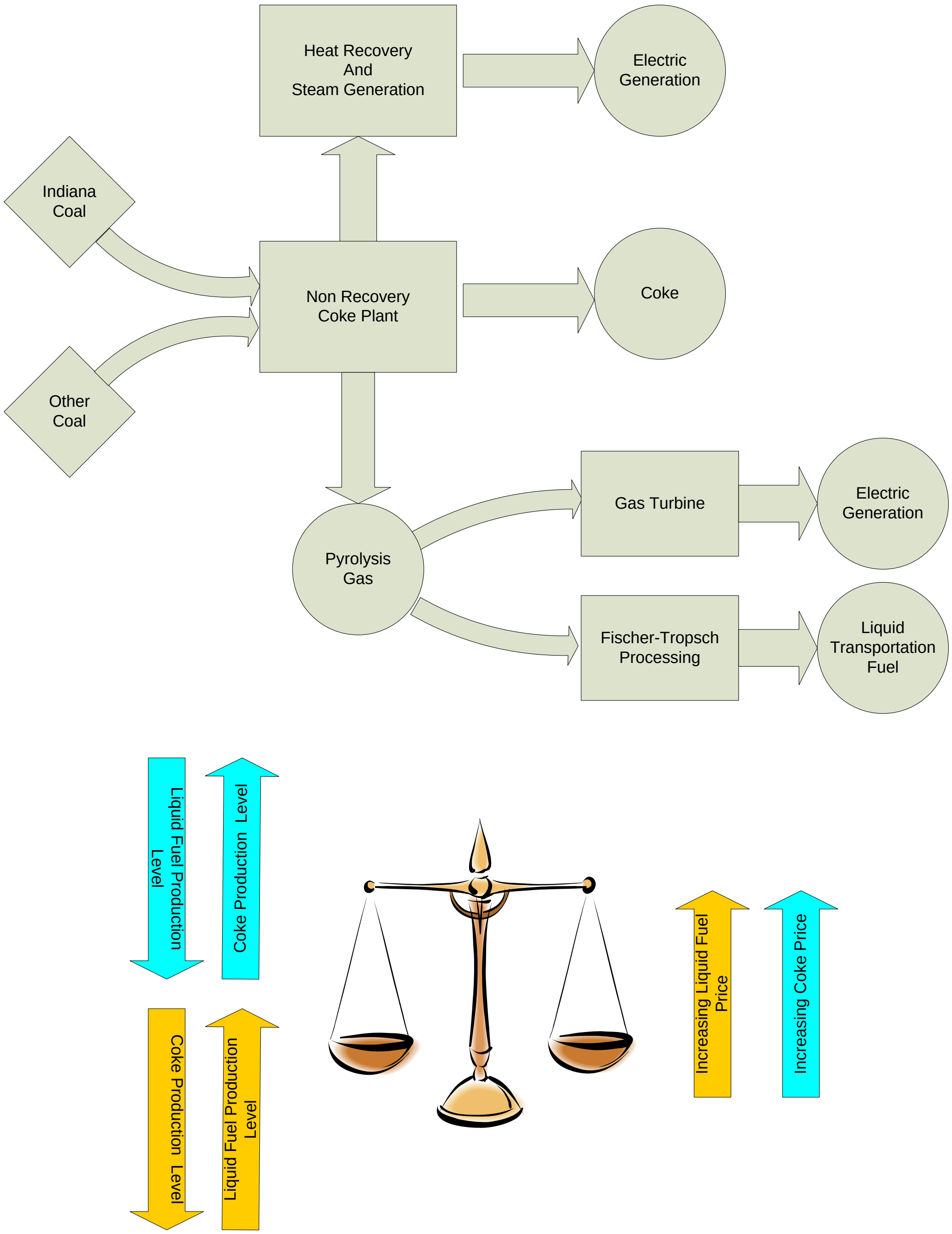


Figure 8: Process Concept and Economic Interactions

Importance to Indiana Coal Use

The central theme of this effort has been to find ways to increase the use Indiana coal in coking and other related industrial operations in a way that increases overall value. By finding ways to increase the use of Indiana coal in such processes, exports of coal from sources outside Indiana will be decreased and there will be a potential to open new markets for Indiana coal.

A mine mouth coking/coal gasification facility will have many positive economic and employment effects for Indiana. This facility will be located in Indiana. Typically, a 1.3 million ton per year coke facility employs about 130 people. In addition, it is estimated that 13 new employees would be required in the Indiana mining industry. A new facility of the type considered would provide a significant employment opportunity for Indiana. Such a facility would allow the Indiana Coal Industry to open a new and expanding market. Metallurgical coal contracts increases by 20% to 40% in 2004.[17] In 2002 Indiana imported 8.093 million tons of coking coal. The potential for use of Indiana coal for coke production for use in Indiana is between 2.0 and 3.6 million tons per year. Export potential is estimated to range from 6 to 11 million tons per year.[18] Current coke production at Indiana Harbor facilities is 1.2 million tons per year screened. The proposed facility would be of a comparable size and would result in an estimated cost savings of at least 5 % for delivered coke due to reduced transportation costs and would meet a portion of future demand growth. It would also reduce imports of metallurgical coal by several million tons per year and replace it with coal produced in Indiana. There would also be a potential to export coke to adjacent States including Ohio, Kentucky, and Illinois. The sale of electric power from the cogeneration function would also result in a significant revenue stream to further enhance the benefit of the project.

Indiana's steel industry is a major employer, as well as significant sources of revenue to the State in the form of taxes. This project will help to assure the health of this vital industry, generate new jobs and revenue streams, and advance the technical state of the art by using Indiana coal and simultaneously reducing environmental emissions.

Environmental emissions are often cited as a reason why Indiana coal is not used in the production of coke. This proposal presents a different option that inverts the classic coke production paradigm. This project proposes to develop a process in which clean coal technology is used at the mine mouth to produce coke, rather than transporting coal from sources outside Indiana to non attainment areas for coke production. Gas streams from the coking process will be collected and used for subsequent production of electricity at the site or possibly the production of liquid transportation fuel. This process will result in a net transportation savings, as well as a value stream from cogenerated electricity. Such a facility will provide base load electric generation, but will also have the capability to supply shoulder and peaking power, in addition to, potentially ancillary services.

The research team for this proposal has extensive experience in the coking process, characterization of Indiana coal coking properties, electric generation, engineering, and system analysis. The major products from the facility will be coke, electricity, and potentially liquid transportation fuel. All are crucial to the economic future of Indiana. The locations of Indiana's coal mines provide many unique advantages for coke production relative to expanded production at current facilities. Special consideration will be given to assure that the proposed process is optimized for the use of Illinois basin coals from Indiana.

This proposal leverages experience from current coking facilities in Indiana. Research will be required to extend these technologies for use in a mine mouth coking facility, but the technical risk will be less than for a completely experimental concept. Such an approach is made possible by the use of proven technology in the new coking paradigm of this proposal. This approach significantly increases the probability that an actual productive facility could operational within a 5 year time frame. Mine mouth coke production with cogeneration will provide many advantages over current production methods. These advantages will also be attractive both within and outside the United States. Due to current market shortages and the price volatility of coke internationally, there is an opportunity to market Indiana coal in a new way in the form of coke to a variety of new markets both within and outside Indiana.

The U.S. coke industry has two primary product markets (i.e., furnace and foundry coke) that are supplied by two producing sectors—integrated producers and merchant producers.[19] Integrated producers are part of integrated iron and steel mills and only produce furnace coke for captive use in blast furnaces. Therefore, much of the furnace coke is produced and consumed by the same integrated producer and never passes through a market. However, some integrated steel producers have closed their coke batteries over the past decade and purchase their coke supply from merchant producers or foreign sources. A small number of integrated steelmakers produce more furnace coke than they need and sell their surplus to other integrated steelmakers. In 1997, integrated producers accounted for roughly 76 percent of U.S. coke capacity with merchant producers accounting for the remaining 23 percent. These merchant producers sell furnace and foundry coke on the open market to integrated steel producers (i.e., furnace coke) and iron foundries (i.e., foundry coke). Some merchant producers sell both furnace and foundry cokes, while others specialize in only one.

Even though captive consumption currently dominates the U.S. furnace coke market, open market sales of furnace coke are increasing. As production costs increase, U.S. integrated steel producers increase their consumption of furnace coke from merchant coke producers, foreign imports, and other integrated steel producers with coke surpluses.

Merchant coke producers account for a small share of U.S. furnace coke production (about 12 percent in 1997); however, they account for 100 percent of U.S. foundry coke production. The U.S. foundry market appears to be fairly concentrated with two companies in 1997 accounting for almost 68 percent of U.S. production.

Figure 8 depicts the influence of cost factors and linkages in the market.[20] In general, captive coke plants supply their excess coke to the furnace coke market with remaining supply from merchant plants and foreign imports. Furnace coke produced at captive coke plants and shipped directly to integrated iron and steel mills owned by their parent companies do not directly enter the market for furnace coke. Environmental compliance costs incurred by captive, or "in-house", furnace coke batteries indirectly affect the furnace coke market through price and output changes in the steel mill products market.

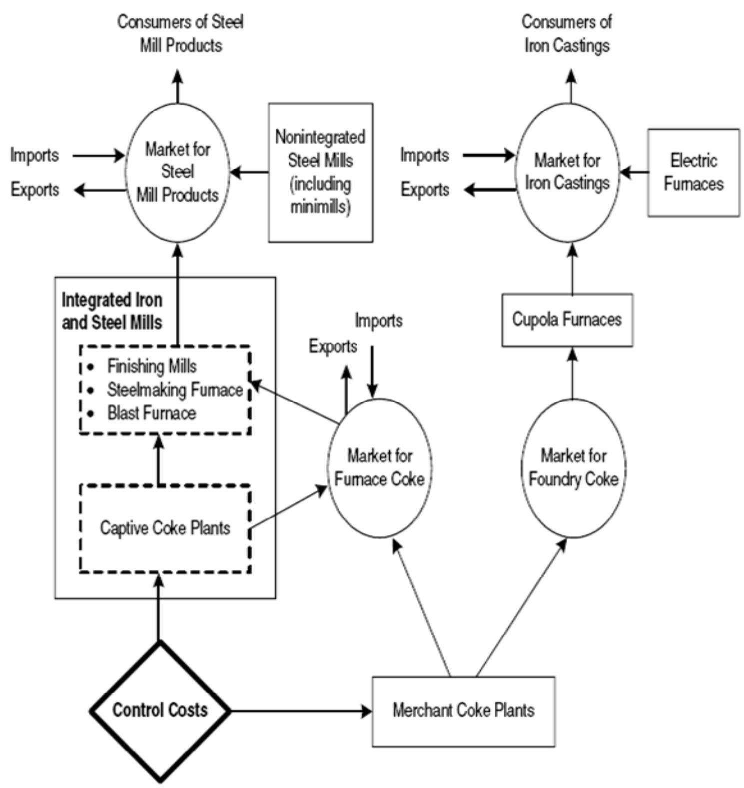


Figure 9: Coke Market Linkages

Relevance to Previous Studies

Coal is an abundant energy resource that has been characterized by a variety of different groups. The availability of this resource provides many opportunities to displace other energy sources such as oil that have high price volatility and supply concerns. The following information from the Energy Information Administration characterizes the availability of coal resources[21].

> Total recoverable reserves of coal around the world are estimated at 1,083 billion tons — enough to last approximately 210 years at current consumption levels. Although coal deposits are widely distributed, 60 percent of the world's recoverable reserves are located in three countries: the United States (25 percent), FSU (23 percent), and China (12 percent). Another four countries—Australia, India, Germany, and South Africa—account for an additional 29 percent. In 2001, these seven countries accounted for 80 percent of total world coal production. Recoverable coal reserves and consumption are depicted if Figures 9 and 10 respectively.

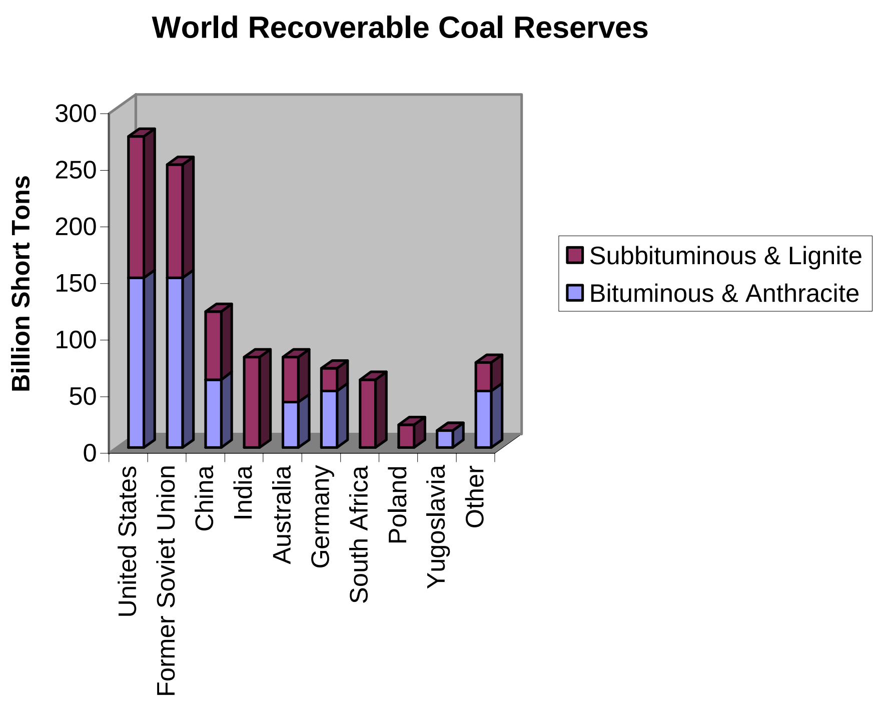


Figure 10: World Recoverable Coal Reserves

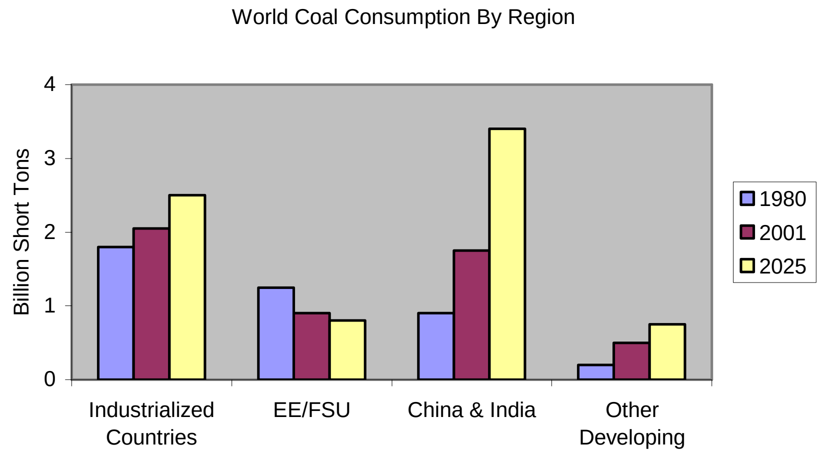


Figure 11: World Coal Consumption by Region, 1980, 2001, and 2025

As can be seen from the previous two figures, coal is an abundant resource and its use is anticipated to expand in the future. This expanding usage provides an opportunity to increase the use of Indiana coal for coking and other purposes. Figure 11 depicts World Coal Trade for 1985, 2002, and 2025[22] and also indicates specifically an increase in coke consumption.

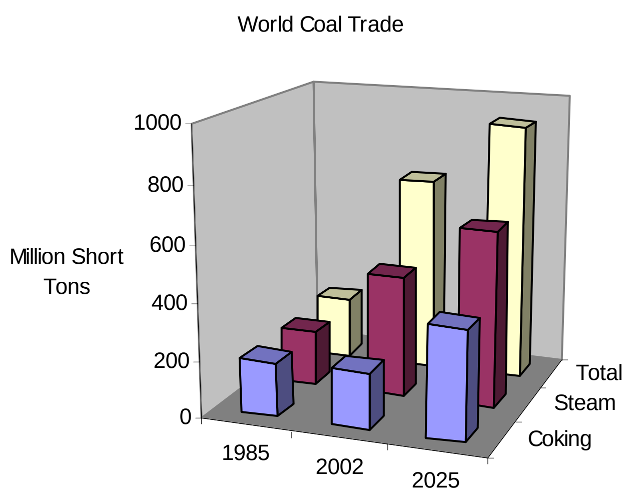


Figure 12: World Coal Trade, 1985, 2002, and 2025

Figure 12 depicts the relative amounts of U.S. coal imports and exports projected to 2025.[23] This figure indicates that there will be an increasing trend to import more coal relative to coal produced domestically. As the fraction of imported coal increases there will be additional pressure placed on coking coal supplies. The proposed technology to use Indiana coal to produce coke could supplement the coal supply for coking purposes and enhance the future market for Indiana coal.

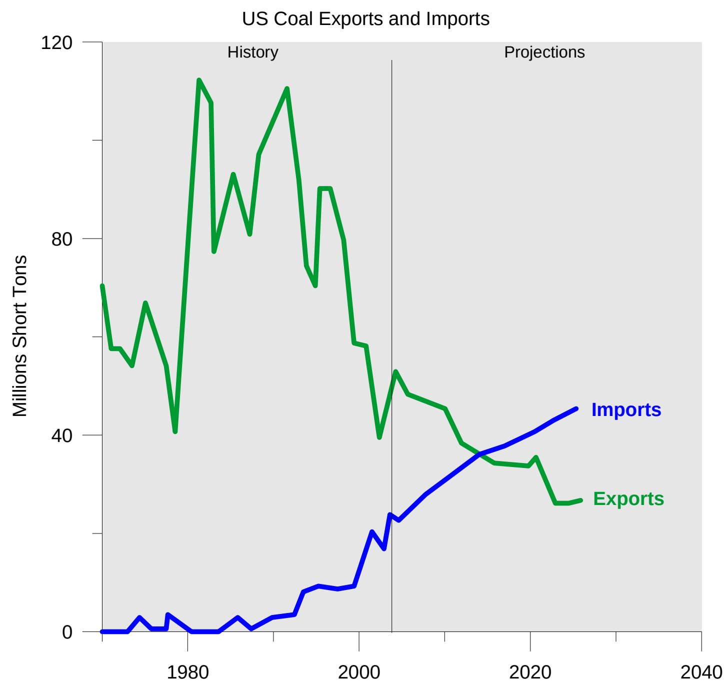


Figure 13: U.S. coal exports and imports, 1970-2025

In the early 1900s Indiana coal was used for coke production.[24] Technology and requirements have changed since this time, but it is now appropriate to again start using Indiana coal for coke production. To accomplish this it will be necessary to develop methods that alleviate issues with using Indiana coal for coke production and simultaneously add value to the process. This proposal presents an approach that is targeted at meeting these requirements.

The particular mix of high- and low-volatile coals used and the length of time the coal is heated (i.e., coking time) determine the type of coke produced: (1) furnace coke, which is used in blast furnaces as part of the traditional steelmaking process, or (2) foundry coke, which is used in the cupolas of foundries in making gray, ductile, or malleable iron castings.[25] Furnace coke is produced by heating a coal mix of 10 to 30 percent low-volatile coal for 16 to 18 hours at temperatures of 2,200°F. Most blast furnace operators use coke sized between 0.75 inches and 3 inches. Foundry coke is also produced by heating a mix of 50 percent or more low-volatile coal for 27 to 30 hours at temperatures of

1,800°F. Coke size requirements in foundry cupolas are a function of the cupola diameter (usually based on a 10:1 ratio of cupola diameter to coke size) with foundry coke ranging in size from 4 inches to 9 inches.[26] The longer coking times and lower temperatures required for foundry coke results in a longer life of these batteries.

As depicted in Figure 14, furnace coke accounts for the majority of coke produced in the United States.[27] In 2000, furnace coke production was roughly 17.7 million short tons, or 85 percent of total U.S. coke production, while foundry coke production was only 1.3 million short tons. Integrated iron and steel producers that use furnace coke in their blast furnaces may either produce this coke on-site (i.e., captive coke producers) or purchase it on the market from merchant coke producers.[28]

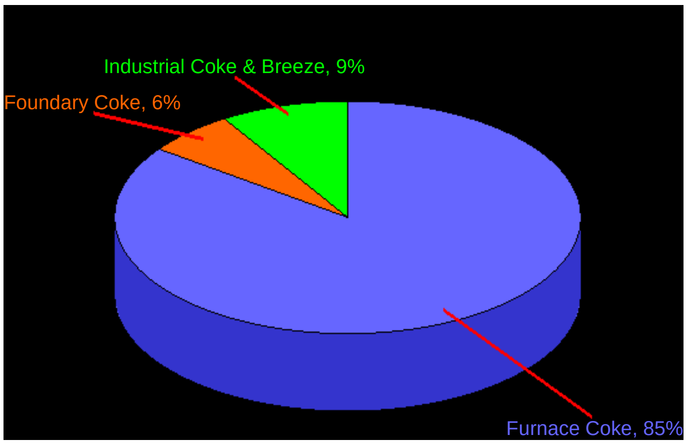


Figure 14: U. S. Coke Production by Type, 2000

Furnace coke also accounts for the majority of domestic coke usage.[29] Figure 15 depicts the world distribution of coals suitable for coke production.[30] Figure 16 depicts world coke production capacity minus consumption. The dotted line in this figure is a minimum level taking into account scheduled and forced outages.[31] It can be observed that the supply of coke is anticipated to increase slightly in the future above the base level in 2004, but will level off at a relatively low value. This will result in a situation of elevated price and need for additional supply. Coke produced from Indiana coal could serve to meet a portion of this demand.

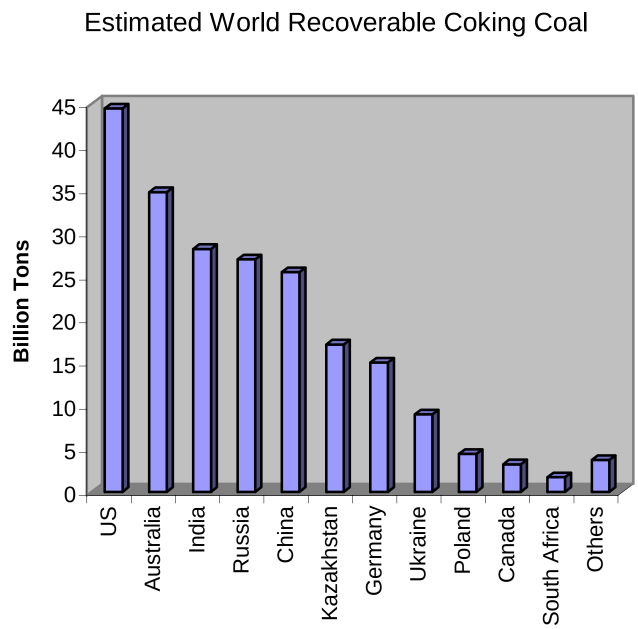


Figure 15: Estimated World Recoverable Coking Coal

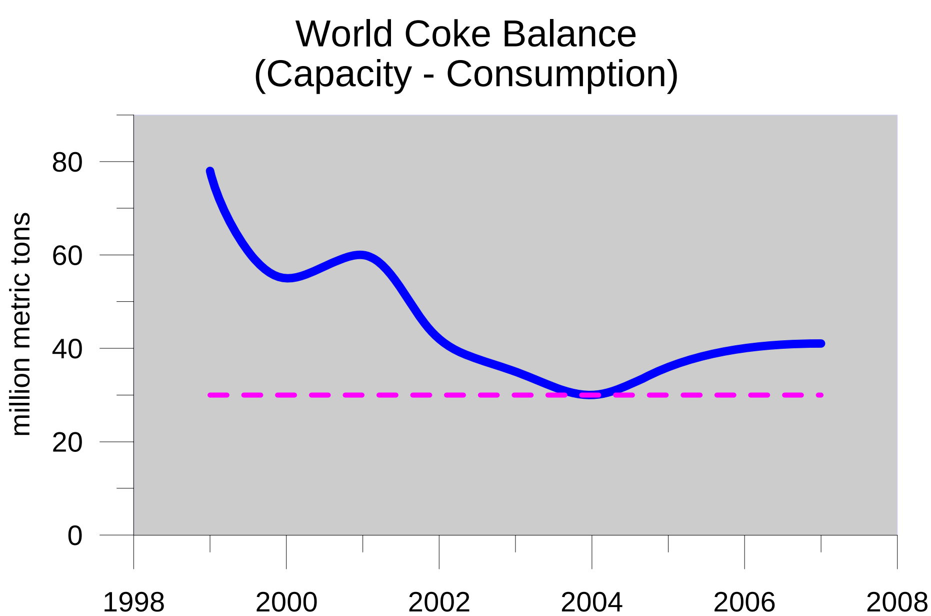


Figure 16: World Coke Balance (Capacity – Consumption)

Due to a variety of circumstances including the tightening of emissions regulations, the number of coke ovens is decreasing as can be seen in Figure 17.[32] This indicates that there is clearly a need for new environmentally friendly coking production capability. The proposed research would support the development of such capability using Indiana coal.

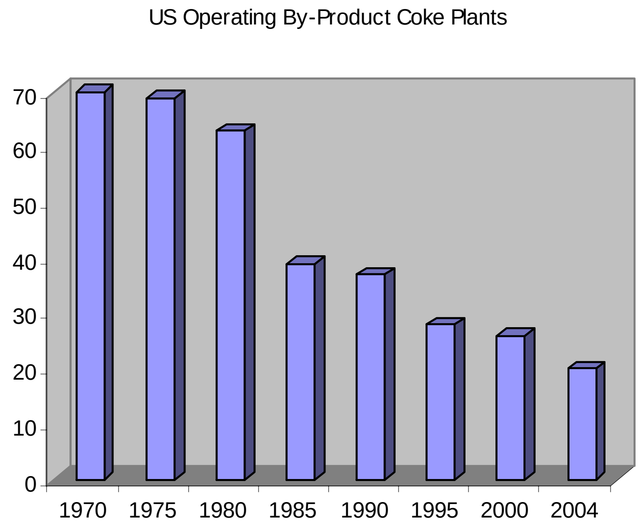


Figure 17: US Operating By-Product Coke Plants

In addition to decreasing numbers, a significant portion of the existing capacity is reaching end of life. Figure 18 depicts coke battery age at Mittal Steel.[33] This also supports the observation that there is need for new environmentally friendly coking production capability. As units reach the end of life, maintenance costs and outages increase dramatically.

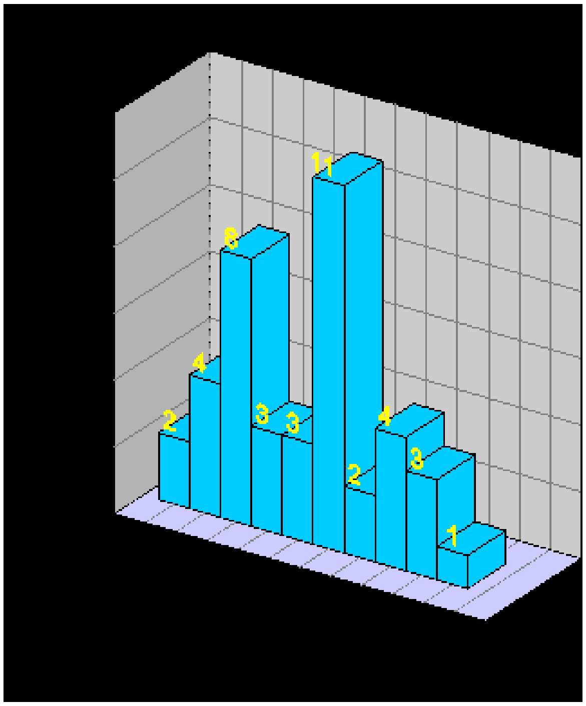


Figure 18: Battery Age – Mittal Steel

Figure 19 depicts the global production of coke[34] and Figure 20 depicts the global consumption of coke products. From this figure it is clear there is a need for new coke production capacity.[35] In general domestic supplies of coke are decreasing while international demand is increasing.[36] The estimated 2.2 billion tons of metallurgical reserves in the U.S. at an assumed consumption rate of 50 million tons per year would result in 40 years worth of recoverable reserves from currently operating mines. Using Indiana coal in the coking process described in this effort could improve economics and extend these reserves.

Competition from China also will increase pressure on domestic coke production facilities. China presently has capacity to produce 208.73 million metric tons of coke per year.[37] Of this 173.73 million metric tons is from slot ovens and the remainder from bee hive ovens. In 2004 China produced 193.7 million metric tons of coke and 50 million metric tons was exported.[38] Currently 180 coke ovens are being constructed in China with a combined production capacity of 60 million tons.

The price volatility experienced recently in China is a result of supply and export policies. In 2001 the cost of coke was $80/ton FOB to a Chinese port. In 2040 it was $410/ton. Currently it is $200/ton.[39] In 2002 Chinese government decreased the number of coke export licenses to meet growing demand.[40] It is anticipated that prices could stabilize at the $200/ton level.[41] This would provide a clear incentive for the construction of additional coke production capacity.

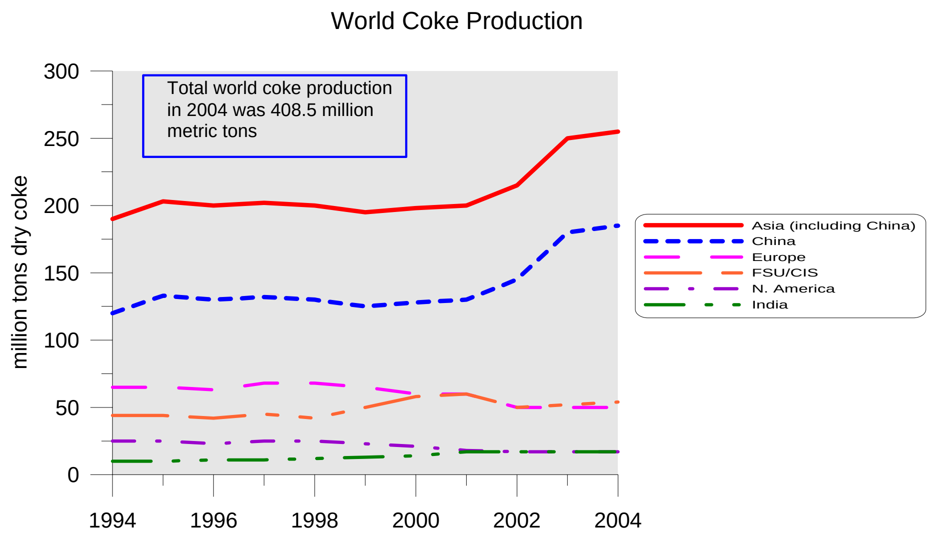


Figure 19: World coke production

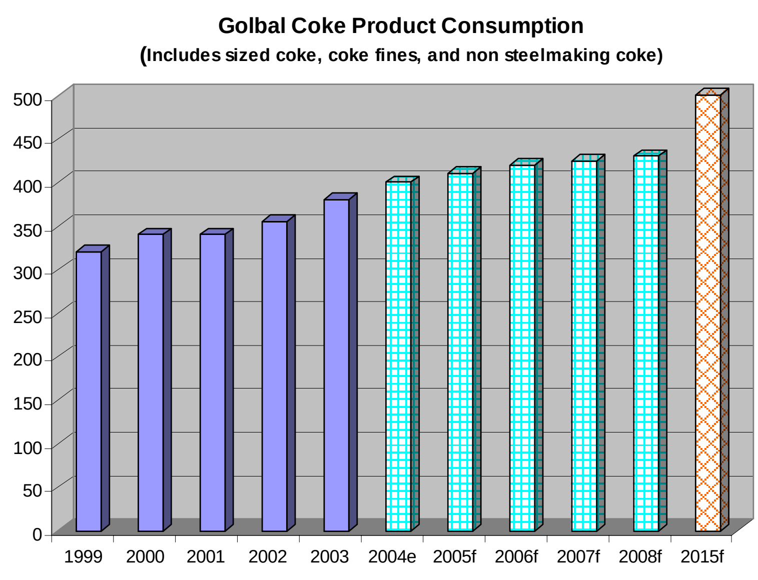


Figure 20: Global Coke Consumption

Producing combustible gases from solid fuels has been done since ancient times. Pyrolysis is a process in which feed material is heated with little air present. Synthesis gas is produced with partial oxidation of the feed material.[42] The coke oven was developed for the metals industry in order to provide a substitute for charcoal during the second half of the eighteenth century. Towards the end of the eighteenth century gas was produced from coal by pyrolysis on a larger scale. In 1812 the London Gas, Light, and Coke Company commercialized gas production. The most important gas produced at this tie was Town Gas. Town Gas can be produced by pyrolysis (producing gas with a heating value of 20,000- 23,000 kJ/m^3) or by the water gas process (coke is converted into a mixture of equal parts of hydrogen and carbon monoxide with a heating value of approximately 12,000 kJ/m^3).[43] Converting part or all of the carbon monoxide into hydrogen produces synthesis gas. This can then be used in Fischer-Tropsch processes for the synthesis of hydrocarbons or acetic acid anhydride. It this context, blast furnaces can be considered to be large gasifiers of coke.[44]

In a recovery coke oven, typically the coke oven gas has a composition of 58% hydrogen, 26% methane, 5.5% nitrogen, 2.25% acetylene, 2% carbon dioxide, 6% carbon monoxide, and .25% oxygen.[45] One metric ton of coal typically produces 600-800 kg of blast-furnace coke and 296-358 m^3 of coke oven gas.[46] This hydrogen content is typically too high for use directly in Fischer-Tropsch processes. Methods to reduce this to the range of a 2 to 1 hydrogen to carbon monoxide ratio, possibly by combining with syngas streams, will be considered. Other processes for removing various constituents from the gas stream including oil, sulfur, and naphthalene will also be considered.[47]

As previously described, if funding is available it would be possible to investigate the development of a hybrid process in which a mixture of pyrolysis and syngas is used to produce liquid transportation fuel through the use of a Fischer-Tropsch process as depicted in Figure 8. Recent advances in nano catalysists will facilitate this development. It is anticipated that this process would be developed in conjunction with an operating coke production facility.

Policy, Scientific and Technical Barriers

In the early 1900s Indiana coal was used for producing coke. As natural gas decreased in price and increased in availability along with decreasing energy costs in general, Indiana coal was used much less for industrial purposes. This also was the result of economics and environmental concerns and to some degree expediency in ramping up steel production levels.

Today, there have been considerable advances in coke oven, emissions control, catalysis, and other related technologies that provide an opportunity to gain operational and economic benefits by using Indiana coal in heavy industrial applications such as the production of coke for blast furnaces. This use will require reconsideration of blending and other process operational functions, but the benefit can be significant. Using tools such as Computational Fluid Dynamics and blending strategies, it is possible to develop methods to significantly increase the level of Indiana coal that could be used to produce coke for blast furnace and other operations.

Issues regarding transportation of coke from central to south western Indiana will need to be considered. It will be necessary to assure that transportation bottlenecks do not negate the benefits. Locating a coking facility at mine mouth will tend to reduce net transportation costs. Issues regarding local emissions requirement will need to be addressed further.

One byproduct of the proposed technology is electricity. It will be necessary to consider associated electric system issues in optimizing the value of generated. Issues regarding integration of the unit into a local control area will need to be addressed as well as any concerns with ancillary electric system services.

Since this technology has the potential to increase sales of Indiana coal as well as creating jobs, there may be possibilities to gain economic development incentives. There is also the possibility that coke markets can be established outside Indiana. Relationships at a state level will need to be arranged for such opportunities.

Further research and development is needed to assed the viability of further developing the technology for the production of liquid transportation fuels through Fischer-Tropsch processes. Research regarding coke oven gas composition, catalysis, processes to use the gas in Fischer-Tropsch processes, and system optimization will be required to assure the feasibility of the concept. It will be necessary to establish contacts for a possible demonstration with either a coal mine or coke facility operator.

Additional Resources Required

Preliminary results indicate that there is significant benefit to continuing with the current research effort and to consider next steps leading to construction of an industrial test facility should additional analysis and development continue to support the concept. Based upon the preliminary results it is recommended that further development of the proposed concept for mine mouth coking/gasification should be initiated and expanded to include consideration of the production of liquid transportation fuels.

The research plan to continue the development of this concept has been divided into two parts. The first part will last one year and will consist of efforts to conduct more detailed process modeling for using Indian coal in industrial processes such as blast furnaces, including consideration of Fischer-Tropsch processes for the production of liquid transportation fuels from coke oven gas. Issues regarding potential transportation and relevant electric system issues will also be considered. It will be necessary to purchase computer hardware and software for the modeling effort.

One of the most important outcomes from this part will be the development of a feasibility study for appropriate portions of the process previously described and depicted in Figure 8. This study will recommend a Go/NoGo decision for the second stage of the project. The feasibility study will be based on modeling results, analysis, and input from various advisory sources including the coal and steel industry. Funding at a level of $100,000 would be required for this part. It is anticipated that of this funding, $15,000 would be devoted to computer equipment and software and the remainder to labor and supply expenses contingent on the treatment of overhead.

The second part of the recommended research plan will last two years and will include development of a test facility to gain further information regarding the value of Indiana coal, alone and in combination with other metallurgical coals, for use in industrial processes. This facility will have the capability of conducting bench-top testing of the processes considered. It will be located in existing laboratory space. It will be necessary to purchase test equipment for the construction of the preliminary process modeling facility.

The characteristics of coke and coke oven gas produced from various blends of Indiana and other metallurgical coals will be tested to assess the viability of using this gas for production of Fischer-Tropsch liquid transportation fuels. Gas blending and conditioning options will be considered. The use of nano catalyst technology for the Fischer-Tropsch as well as possible carbon dioxide sequestration processes will also be considered. A preliminary economic study of the proposed concept will conducted. This will include issues regarding the value of coke, electricity, and possibly electric ancillary services.

One of the most important outcomes from this part will be the development of a feasibility recommendation for the next step of the development which would be to construct a demonstration facility at a coal mine or operating coke plant. Funding at a level of $600,000 would be required for this part. It is anticipated that of this funding, $200,000 would be used to purchase and installing equipment for the test facility, $10,000 would be used to purchase computer equipment and software, and the remainder would be expended on labor and supplies contingent upon treatment of overhead.

Research Plan

The following research plan is presented as a possible way of continuing and expanding the effort that is the subject of this final report. Preliminary results indicate that there is significant benefit to continuing with the current research effort and to consider next steps leading to construction of an industrial test facility should additional analysis and development continue to support the concept. Based upon the preliminary results it is recommended that further development of the proposed concept for mine mouth coking/gasification should be initiated and expanded to include consideration of the production of liquid transportation fuels.

Major Tasks, Issues, and Timeline

The work for the extension of the current research effort will be managed, consistent with the Timeline and Milestones and Task schedule depicted in Figures 21 and 22, consistent with the funding level. Tasks will be as follows;

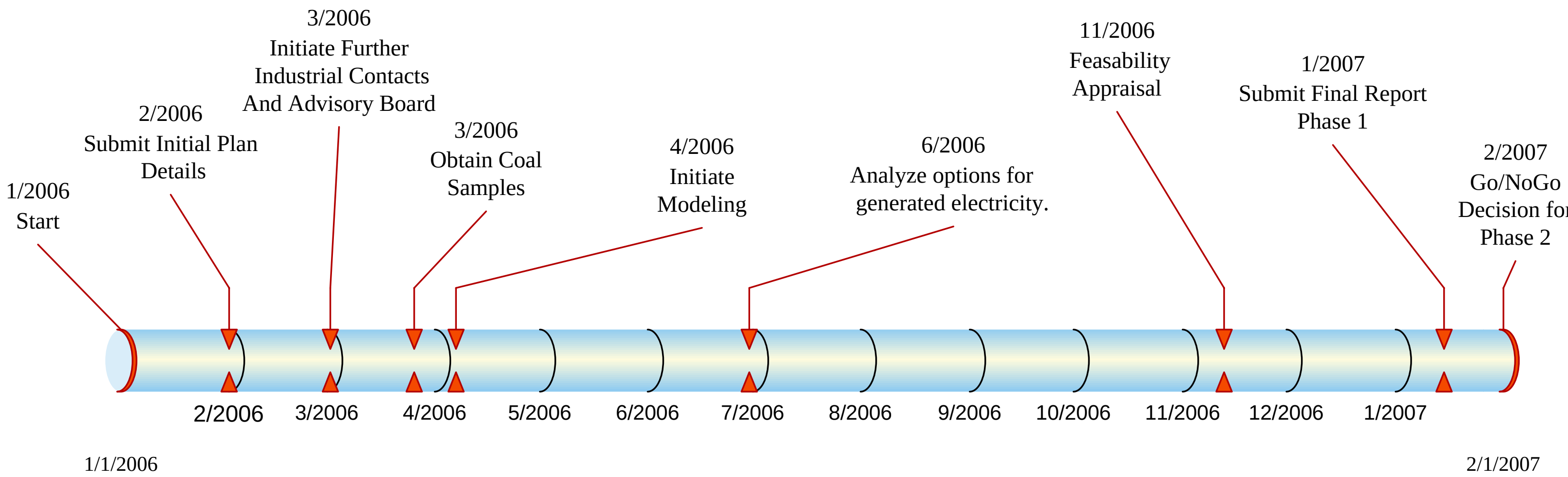
Tasks and Milestones (anticipate funding level: $100,000, 1 year duration)

1. Develop initial plan details and submit for approval – A detailed work plan for the project will be developed during the first three weeks. This plan will assist in establishing a clear understanding of work activities, schedule, and reporting requirement details for all parties to the project.
2. Establish new and refine existing interface with industry contacts – Contacts with industrial, governmental, regulatory, technical, and other appropriate sources will be formalized. Communication and information exchange procedures will be established to provide assistance in assuring the success of the project.
3. Obtain data and models for pyrolysis and Fischer-Tropsch processes.
4. Obtain coal samples and initiate analysis and evaluation of coking and Fischer-Tropsch processes for producing liquid fuels.
5. Initiate investigation of using nano catalysist for gas composition changes and Fischer-Tropsch processes.
6. Initiate non recovery coke oven and pyrolysis modeling.
7. Perform initial Computational Fluid Dynamics scoping appraisal of influence of produced coke on blast furnace operations.
8. Analyze the feasibility and options for using or selling generated electricity.
9. Initiate discussions with coal mine and coke production facilities regarding feasibility of developing a facility.
10. Determine impact of transportation issues.
11. Evaluate economic factors and influence on use of Indiana coal.
12. Develop process feasibility appraisal.
13. Make recommendations for a go/no-go decision point for future research.
14. Prepare final report.

Phase 2 (anticipated funding level: $600,000, 2 years duration)

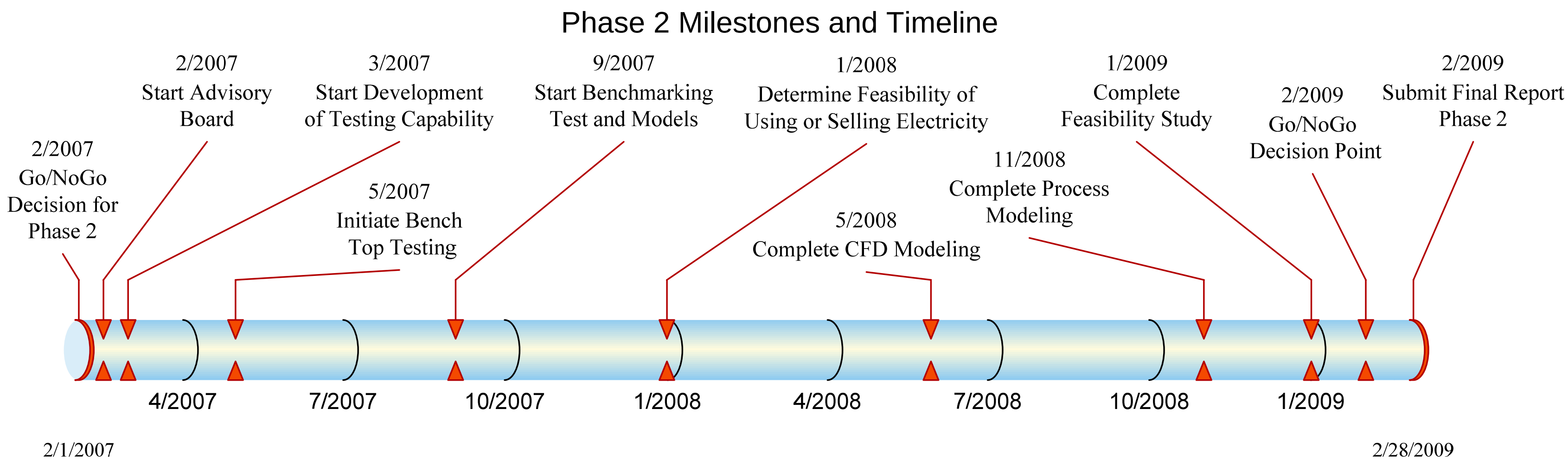
1. Initiate discussions to obtain additional funding for the development of an onsite industrial prototype test of the process. Initiate an advisory group for the industrial prototype test.
2. Expand and complete coal sample analysis and appraisal. Complete an assessment of available Indiana coal sources and their value for coking. Coordinate this with mine owners to evaluate feasibility of coal supply and potential plant locations.
3. Construct bench top prototype testing facility for the processes and conduct tests. This facility will be used to gain information regarding the proposed processes and their feasibility. Coordinate this effort with production personnel from operating coking facilities.
4. Complete initial non recovery coke oven and pyrolysis modeling.
5. Perform preliminary Computational Fluid Dynamics appraisal of initial design. This will facilitate the interface of this project with ongoing research efforts regarding blast furnace operation and optimization.
6. Determine the feasibility and options for using or selling generated electricity.
7. Perform initial economic evaluation.
8. Obtain letters of support from potential industrial participants in the prototype test.
9. Prepare and submit proposals to obtain additional funding for the development of an onsite industrial prototype test of the process.
10. Develop technical feasibility study.
11. Develop coal market impact evaluation.
12. Initiate discussions with coal mines, coke producers, and interested parties regarding construction of onsite industrial prototype test.
13. Make recommendations for a go/no-go decision point for efforts to pursue construction of an industrial test at an operating mine or coking facility.
14. Prepare final report – A detailed final report will be prepared and presented within 30 days of the completion of the project.

Phase 1 Milestones and Timeline



ID	Task Name	Start	Finish	Duration	2006			
					Q1	Q2	Q3	Q4
1	Develop Initial Plan Details	1/2/2006	2/1/2006	23d				
2	Initiate Further Industry Contacts	1/16/2006	6/1/2006	99d				
3	Obtain Coal Samples	2/1/2006	4/3/2006	44d				
4	Modeling for coke oven, Fischer-Tropsch & nano catalysist	3/1/2006	11/1/2006	176d				
5	Analyze options for generated electricity.	6/1/2006	9/1/2006	67d				
6	CFD Scoping Analysis	3/1/2006	9/29/2006	153d				
7	Evaluate Economic Facotrs	4/3/2006	10/31/2006	152d				
8	Develop Process Feasibility Appraisal	6/1/2006	12/29/2006	152d				
9	Prepare Final Report	9/1/2006	1/15/2007	97d				

Figure 21: Research Extension Phase 1



ID	Task Name	Start	Finish	Duration	2007				2008				
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1	Initiate Funding Discussions & Advisory Group	2/15/2007	2/2/2009	513d									
2	Expand Coal Sample Analysis & Appraisal	3/15/2007	9/17/2007	133d									
3	Develop Bench Top Protype Test Capability & Conduct Testing	4/2/2007	1/1/2009	459d									
4	Process Modeling	4/2/2007	1/1/2009	459d									
5	CFD Design Analysis	5/1/2007	11/3/2008	395d									
6	Determine Feasibility of Using or Selling Electricity	1/1/2008	6/2/2008	110d									
7	Economic Evaluation	1/1/2008	1/1/2009	263d									
8	Develop Technical Feasibility Appraisal	1/1/2008	1/1/2009	263d									
9	Develop Coal Market Impact Evaluation	4/1/2008	1/1/2009	198d									
10	Discussions for Demonstration Project	4/2/2008	2/2/2009	219d									
11	Recommendations for Go/NoGo Decision	10/1/2008	2/2/2009	89d									
12	Prepare Final Report	9/1/2008	2/27/2009	130d									

Figure 22: Research Extension Phase 2

Project personnel include:

Robert Kramer (Ph.D.) is Director of the Purdue University Calumet Energy Efficiency and Reliability Center. Dr. Kramer will serve as the Principal Investigator, coordinate the efforts, and maintain the overall program for this proposal. His areas of expertise include energy research, electric system design and operation, engineering, physics, Combined Heat and Power system design and operation, environmental engineering, and project management. Currently his research interests include the simultaneous optimization of Combined Heat and Power systems and renewable energy systems, electric system reliability and quality, and coal coking systems. He has over 30 years of industrial experience in the energy field, most recently as the Chief Scientist for NiSource. He has previously served as principal investigator for three Department of Energy research contracts with budgets totaling over $6.5M. He is currently the principal investigator for projects with a value of $1.5M. He also teaches various courses in Physics and Engineering.

Chenn Zhou (Ph.D.), Professor of Mechanical Engineering Purdue University Calumet. Dr. Zhou is an expert in computational fluid dynamics. She is the principal investigator for a $1.29M 21st Century Grant to develop Computational Fluid Dynamic techniques for use in blast furnace operations. She has modeled various industrial systems and has considered energy and process optimization as part of the modeling effort. Recently, she was elected a Fellow of the American Society of Mechanical Engineers.

Harvey Abramowitz (Ph.D.), Professor**,** Department of Mechanical Engineering, Purdue University Calumet. Dr. Abramowitz has had extensive experience in metallurgy and steel making processes in general. He has worked in the steel industry and is familiar with steel and iron quality and production issues. He has also worked on process costing and economics.

Hardarshan Valia (Ph.D.), President, Coal Science, Inc. Dr. Valia will serve as a team member and consultant to the project. He has extensive experience in the steel industry and specifically in the utilization of coal and the coking process. He also has experience with various production and economic aspects of both the coal and steel industry.

Anita Katti (Ph.D.), Associate Professor, Department of Chemistry and Physics, Purdue University Calumet. Dr. Katti has a background in chemical engineering from the pharmaceutical industry. Her current interests include modeling of chemical processes and systems.

Liberty Peltier (Ph.D.), Assistant Professor, Department of Chemistry and Physics, Purdue University Calumet. Dr. Pelter has a background in surface chemistry and catalysis from the petroleum industry. Her current interests include development of nano catalysis and surface chemistry.

It is anticipated that various faculty from Purdue University Lafayette will also collaborate in the effort. There will also be an opportunity for student participation in research activities. This will assist in assuring that technically knowledgeable personnel that are familiar with the project concepts are available for employment in an actual operating facility. There will also be an added benefit of helping to retain graduates of Indiana's universities in Indiana jobs.

Detailed resumes are attached in the appendix.

Contact Information:

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Potential Sources of Matching Funding

The funding for follow on efforts will be leveraged with other funding sources. It is anticipated that additional funding may become available from sources including the Department of Energy, the Indiana 21st Century Fund, steel producers, coal mines, and coke producers.

During phase one, proposals for additional funding will be prepared and as appropriate at the start of phase two they will be submitted to the funding sources. During both phase one and two advice and guidance for additional funding will be solicited from advisory board members and industry in general.

Conclusion

This study has shown that it is highly likely that Indiana coal can become an important resource for the production of coke for the steel and other industries both inside and outside Indiana. As was noted in the study, currently there is a shortfall of 5.50 million tons of coke per year in the United States. This research effort has shown that Indiana coal can become one way to reduce current and future coke supply issues as well as reducing price by as much as 10%.

The significant shortfall of needed coke has placed an enormous strain on Indiana's steel and foundry industries. The need for additional coke production capacity is evident given plans for coke plant expansion being considered by Indiana's steel industry and others. This results of this study indicates that the coke supply and high price volatility situation can be mitigated through the use of Indiana coal in a mine mouth, environmentally friendly, high efficiency coking/coal gasification facility. Such a facility would also increase coke supply and production, while, at the same time, reducing the cost for Indiana's steel and foundry industry. In addition, such a high efficiency coking facility would produce electricity for sale to the wholesale electric market, thereby reducing costs and environmental emissions and, at the same time, enhancing electric system reliability.

The following are major results from this study:

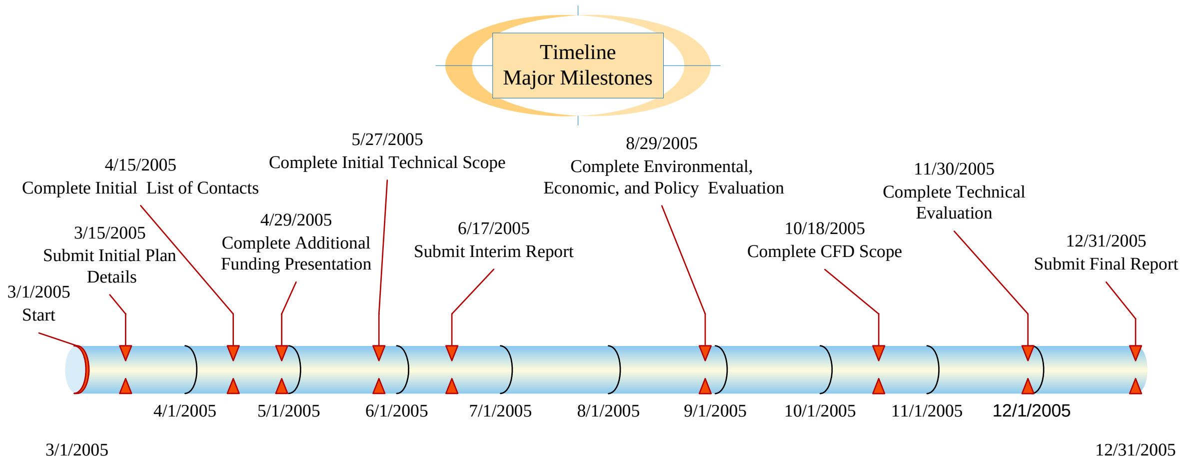
1. There is a high probability that a mix of Indiana Brazil Seam or potentially other Indiana coals, as previously identified by the Indiana Geological Survey, could be blended with other coals to meet metallurgical and emissions requirements.
2. There is interest in the coal and steel industry to consider establishing a coke production process at an Indiana coal mine. Moreover, there may be an opportunity to consider the value of some emissions credits, due to the "clean coal technology" as well as the different geographic location.
3. The total transportation cost would be reduced, since the mass of the product coke is less than the coal needed to produce it and also because coke is less dense than coal. Thus, a significant cost savings from the reduced weight per mile of material being transported would result.
4. Preliminary results indicate that it is highly likely that a coking/coal gasification process can be developed that would produce metallurgical grade coke using a significant percentage of Indiana coal and, at the same time, would produce a byproduct gas stream that would be usable in a cogeneration facility for the production of electricity to be sold in the electric market. Preliminary Computational Fluid Dynamic results from current blast furnace modeling efforts indicate that it may be possible to increase the percentage of coke produced from Indiana coal blended with coke from other coals in blast furnace operations.

5. With a mine mouth operation, blending and storage of coal feed streams would be done on site and would thus allow for scheduling the production of electricity to correlate with times of high market value.
6. Preliminary discussions and analysis indicate that there is a possibility to utilize coke oven gas to produce liquid transportation fuels by means of a Fischer-Tropsch process, possibly enhanced with nano catalyst technology. There are also indications that it may be possible to sequester carbon dioxide as part of the process.

The work for this proposal started in March 2005 and was completed in November 2005. All the tasks from the original milestone and schedule chart, depicted in Figure 23, were completed on schedule. It was possible to initiate discussions and produce interest in this technology through discussions with a variety of parties including steel mills and coke producers.

Indiana's steel and foundry industries are major employers, as well as significant sources of revenue to the State in the form of taxes. This project would help to assure the health of these vital industries, generate new jobs and revenue streams through the use of Indiana coal at a facility to be located in Indiana, and advance the technical state of the art by using Indiana coal and simultaneously reducing environmental emissions. A recommendation for continuation and extension of this effort is included in this final report.

All the tasks described in the following schedule were completed on time in accordance with the following schedule.



Task Schedule

ID	Task Name	Start	Finish	Duration
1	Develop Initial Plan Details and Submit to CCTR for Approval	3/1/2005	3/15/2005	11d
2	Establish Interface With Industry Contacts	3/1/2005	4/15/2005	34d
3	Prepare Presentation for Expanded Project and Additional Funding	3/15/2005	4/29/2005	34d
4	Prepare Initial Technical Scoping Study	3/15/2005	5/27/2005	54d
5	Prepare Interim Report	5/2/2005	6/17/2005	35d
6	Prepare Environmental, Economic, and Policy Evaluation Scoping Report	4/15/2005	8/29/2005	97d
7	Evaluate CFD Aspects	6/16/2005	10/18/2005	89d
8	Technical Evaluation	4/18/2005	11/30/2005	163d
9	Prepare Final Report	9/15/2005	12/30/2005	77d

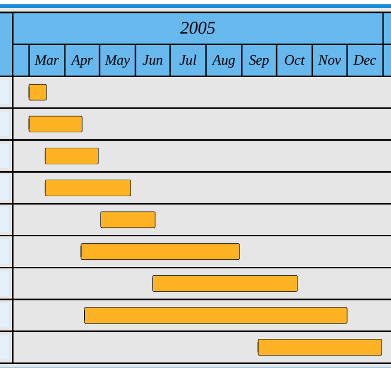


Figure 23: Completed Tasks and Schedule

Appendix

Resumes

Robert Kramer, Ph.D.

Director, Energy Efficiency and Reliability Center
Purdue University Calumet
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Robert A. Kramer is currently the Director of the Energy Efficiency and Reliability Center at Purdue University Calumet. In this role he is involved in the development of research programs in energy utilization and efficiency as well as electric power, reliability, transmission, renewable and Combined Heat and Power systems, and coal and coking applications. He also teaches various courses in Engineering and Physics.

Prior to coming to Purdue University Calumet he was the Chief Scientist for NiSource Energy Technologies and most recently was responsible for technical developments of new energy technologies including Combined Heat and Power Systems. He was at NiSource from 1973 until January 2004 and held the positions of Nuclear Fuel Engineer, Manager Applied Research, Manager Strategic Planning, Manager Technical Support, Director of Electric Engineering and Applied Research, Director of Electric Operations, Director of Electric Services, Vice President, and Chief Scientist. During this time, he also taught a variety of courses in Physics and Engineering at Purdue University Calumet and Indiana University Northwest.

Dr. Kramer has developed various Combined Heat and Power (CHP) systems. These systems involve the local generation of electricity along with the use of waste heat in cogeneration cycles thereby greatly increasing efficiency to above 72%. Energy sources such as microturbines, reciprocating engines, fuel cells, and solar systems were considered in this work. These systems involve advanced optimizing control systems that include neural networks and are fuzzy logic based and are integrated with and often replace the conventional building control systems thereby greatly increasing efficiency.

He has worked closely with various local and national industries in an effort to develop new concepts for process and energy modeling and optimization. He has also worked with the North American Electric Reliability Council on the development of concepts and procedures for the monitoring and improvement of the reliability of the national electric transmission system. He has served as the principal investigator for three Department of Energy research contracts with a total value of over $6,500,000 as well as being one of the co founders of the Center for Advanced Control of Electric Power Systems funded by the National Science Foundation and the Electric Power Research Institute.

He currently serves as the principal investigator for research grants totaling approximately $1.5M. He has also received a guest appointment to the Laboratory of Renewable Resource Engineering at Purdue University Lafayette, Indiana and is a member of the Executive Board of the Purdue Lafayette Energy Center.

Dr., Kramer received a Ph.D. (1985) and M.S. (1979) in Nuclear Engineering from Purdue University, West Lafayette, Indiana, and B.S. (1971) and M.S. (1973) degrees in Physics, also from Purdue University, West Lafayette.

He has published numerous papers regarding energy systems, energy economics, technical and reliability issues associated with deregulation, combined heat and power, and control of highly varying industrial loads. He has participated in a variety of industry committees including the Coordination Review Committee (CRC) for the East Central Area Reliability Council (ECAR), the Research Advisory Committee (RAC) for the Electric Power Research Institute (EPRI), the Basic Science Committee of the Gas Research Institute, and the Control Criteria Task Force, Performance Sub committee, and other committees of the North American Electric Reliability Council. He is a former president of the Calumet Engineering Education Association.

He is a Senior Member of The Institute of Electrical and Electronics Engineers (IEEE) and The Association of Energy Engineers (AEE). He is also a member of the American Physical Society (APS), American Nuclear Society (ANS), American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), the Association of Iron and Steel Engineers (AISE), the American Institute of Aeronautics and Astronautics (AIAA), and the Sigma Pi Sigma physics honorary.

Dr. Kramer also holds three patents. A listing of his publications and patents follows;

Publications

Kramer, R., “Mine Mouth Coking/Coal Gasification Energy Optimization Study”, Proceedings of American Institute of Aeronautics and Astronautics 3rd International Energy Conversion Engineering Conference, August 2005.

Kramer, R. “CHP System Dynamic Optimization in Conjunction with Renewable Resources”, Proceedings of American Institute of Aeronautics and Astronautics 2nd International Energy Conversion Engineering Conference, August 2004.

Kramer, R., “System Integration of Distributed Generation for Complete Building Systems, Final Report”, National Renewable Energy Laboratory Report to be published in 2005.

Kramer, R., “System Integration of Distributed Generation for Complete Building Systems, report 2”, National Renewable Energy Laboratory Report NREL/SR-560-35054, 2003.

Kramer, R., “System Integration of Distributed Generation for Complete Building Systems , report 1”, National Renewable Energy Laboratory Report NREL/SR-560-34966, 2003.

Chang-Chien, L., Ong, C., Kramer, R., “Field Test and Refinements of an ACE Model”, Institute of Electrical and Electronics Engineers Transactions on Power Systems, Vol 18, No. 2, May 2003.

Chang-Chien, L., Ong, C., Kramer, R., “Estimation of β For Adaptive Frequency Bias Setting in Load Frequency Control”, Institute of Electrical and Electronics Engineers Transactions on Power Systems, Vol 18, No. 2, May 2003.

Kramer, R., Shoureshi, R., Thomas, H., “Intelligent Control for Optimal Hybrid Power System in Commercial Buildings”, Second International Symposium on Distributed Generation Conference Proceedings, Stockholm, Sweden, October 2002.

Hoonchareon N., Ong C., Kramer R., “Feasibility of Decomposing Ace to Identify the Impact of Selected Loads on CPS1 and CPS2”, Institute of Electrical and Electronics Engineers Transactions on Power Systems, Vol 17, No. 3, Aug 2002, pp 752-756.

Hoonchareon N., Ong C., Kramer R., “Implementation of an ACE Decomposition Method”, Institute of Electrical and Electronics Engineers Transactions on Power Systems, Vol 17, No. 3, Aug 2002, pp757-761.

Hoffner B., Shoureshi R., Kramer R., “Feedforward Neural Fuzzy Control of Electric Power Sysdtems Containing Highly Varying Loads”, in American Control Conference Proceedings, December, 2002.

Siriariyaporn V., Gotham D., Kramer R., Sparrow F., “Measuring the Cost of Providing the Regulation Ancillary Service with Highly Varying Loads”, North American Power Symposium, ASU, May 2002.

Hoffner B., Shoureshi R., Kramer R., “Development of an Intelligent Automatic Generation Control System for Electric Power Plants”, in International Mechanical Engineering Congress & Exposition Proceedings, 2002.

Shoureshi R., Hoffner B., Kramer R., “Neural-Based Generation Control for Highly Varying and Uncertain Loads”, Power Tech Conference, Institute of Electrical and Electronics Engineers, Porto, Portugal, 2001.

Shoureshi R., Li H., Kramer R., Klaiman H., “Intelligent Control for Electrical Power Generation Systems”, in Proceedings of the ASME Dynamic Systems and Control Division, DSC-Vol. 61, 1997.

Gaul S., McGill M., Kramer R., Compressed Air Energy Storage Offers Flexibility For Low Cost Providers of Electricity, in “Power-Gen 95 Proceedings”, Anaheim , CA, December 1995.

Kramer R., “In the Midst of Change”, Transmission and Distribution (magazine), January 1994.

Heydt G., Karipides D., Shoureshi R., Wheeler M., Kramer R., Stears M., “Active and Reactive Power Flow for Multi-area Systems on Automatic Generation Control in the Presence of Rapidly Changing Loads”, Journal of Electric Machines and Power Systems, 1994.

Stears M., Heydt G., McGranaghan M., Wagenblast G., Kramer R., Samotyj M., “Characterizing Highly Varying Loads Associated With the Steel Industry”, in 1993 Electric Power Research Institute Power Quality Conference proceedings, San Diego, California, November 1993.

Douglas L., Green T., Kramer R., “New Approaches to the AGC Non-conforming Load Problem, in IEEE-PICA’93 Conference Proceedings, Phoenix Arizona, May 1993.

Kramer R., “Maintaining Power Quality and Reliability in a Changing Environment”, in VI Latin IVERO American Conference on Operations Research proceedings, Mexico City, Mexico, October 1992.

Kramer R., “Changes in the Electric Utility Industry will Provide Increased Engineering Challenges as Well as Benefits”, Transmission and Distribution (magazine), January 1992

Kramer R., “Analytic and Operational Consideration of Electric System Reliability”, in Iron and Steel Exposition proceedings, Pittsburgh, Pennsylvania, September 1991.

Kramer R., “Electric System Reliability in a Changing Utility Environment”, in American Power Conference proceedings, Chicago Illinois, April 1991.

Kramer R., “Maintaining Industrial Power Quality in a Changing Utility Environment”, in 1991 Annual Reliability and Maintainability Symposium proceedings, Orlando, Florida, January 1991.

Kramer R., Jacobs R., “Weathering-Steel H-Frames Support New 345-KV Line, Transmission and Distribution (magazine), June 1990.

Kramer R., “Consideration of Heavy Industrial Load in Regard to Electric System Reliability”, in American Power Conference proceedings, Chicago, IL, April 1990.

Kramer R., “Improving Transmission Line Reliability”, in T&D World Expo 90 proceedings, Indianapolis, IN, March 1990.

Kramer R., Adams T., “Power-Quality Program Detects Substation Problems”, in T&D World Expo 90 proceedings, Indianapolis, IN, March 1990.

Kramer R., Adams T., “Evaluation of Substation Physical State by use of Harmonic and Transient Monitoring Equipment”, in American Power Conference proceedings, Chicago, Illinois, April 1989.

Kramer R., Vance R., “Automated Construction Budget With Cost Benefit Prioritization”, in American Power Conference proceedings, Chicago, Illinois, April 1989.

Kramer R., “Time Dependent Behavior of Distribution Systems Containing Repairable Components”, in Second International Symposium on Probabilistic Methods Applied to Electric Power Systems proceedings, Oakland California, September 1988.

Kramer R., “Consideration of Time Dependent Failure Rates in the Analysis of Electric Distribution and Liquefied Natural Gas Storage Systems”, in 14th Inter-RAM Conference for the Electric Power Industry, Toronto Canada, May 1987.

Kramer R., “Application of Probabilistic Risk Assessment to the Analysis of Gas System Reliability”, in 1986 International Gas Research Conference proceedings, Toronto, Canada, September 1986.

Kramer R., “Application of Probabilistic Risk Assessment Techniques to Electric Power Systems”, in International Symposium on Probabilistic Methods Applied to Electric Power Systems proceedings, Toronto, Canada, June 1986.

Kramer R. and Gailar O., “Influence of Generating System Reliability on Power Plant Operations Decisions”, in 12th Inter-RAM Conference for the Electric Power Industry proceedings, Baltimore, Maryland, April 1985.

Kramer R. and Gailar O., Sensitivity of Alternative Nuclear Fuel Cycles to Plant Operating Conditions, in “Electric Power Utility Research Conference Proceedings”, Midwest Energy Research Consortium, Chicago, Illinois, 1984.

Kramer R. and Gailar O., “Application of Computer Graphics to Safeguards and Security Analysis”, Journal of the Institute of Nuclear Materials Management, Fall 1981.

Kramer R. and Gailar O., “Isotopic Inventory Prediction Employing A Monte Carlo Dancoff Factor”, Journal of the Institute of Nuclear Materials Management, Fall 1980.

Kramer R. and Gailar O., “Improved Isotopic Inventory Prediction Methods”, Journal of the Institute of Nuclear Materials Management, Spring 1979.

Kramer R. and Gailar O., “A Modification of the LEOPARD Computer Program in Order to Improve Isotopic Inventory Prediction Accuracy”, Journal of the Institute of Nuclear Materials Management, Fall 1978.

Patents

US Patent No. 6,757,591 B2, Energy Management System and Methods for the Optimization of Distributed Generation, 6/29/2004.

US Patent No . 4,646,940, Method and Apparatus for Accurately Measuring Volume of Gas Flow as a Result of Differential Pressure, 3/3/1987

US Patent No. 4,914,275, Regasifier, 4/3/1990

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Areas of Research Interest

- Cryogenic treatment of tool steels
- Application of new experimental techniques to fatigue testing
- Treatment of metal bearing wastes for metal recovery
- Development of nonpolluting processes for metal production

Professional Experience

Academic Appointments

2003-present	**Professor,** Department of Mechanical Engineering, Purdue University Calumet. Responsible for all courses in Materials Science and Metallurgy. Also teach Introduction to Engineering Design and a course in Solid Waste Management.
1993-2003	**Associate Professor**, Department of Engineering Developed a post baccalaureate program in Iron and Steel Metallurgy. In 1999, a group of 10 engineers from Hadeed Steel Company, Saudi Arabia were the first to complete the program.
2000-2002	**Visiting Professor**, Department of Materials Science – Steel Research Center, Northwestern University. Participated in freshman and upper level design courses. Learned techniques in the computer design of alloys.
1991	**Summer Fellow**, Faculty Research Participation Program, Chemical Technology Division, Argonne National Laboratories, Lemont, IL. Theoretical work on thermodynamic analysis of new treatment method for disposing of the metal wastes from the Integral Fast Reactor.
1988-1993	**Assistant Professor**, Department of Engineering, Purdue University Calumet
1987-1988	**Visiting Assistant Professor**, Department of Engineering, Purdue University Calumet
1987	**Adjunct Associate Professor**, Department of Metallurgy, University of Missouri, Rolla, MO. Developed and taught course entitled "Metallurgical Plant Design and Economics."
1986	**Visiting Scholar**, Department of Metallurgy, University of Missouri, Rolla, MO. Developed research projects for the recovery of the metal content from waste materials.
1979-1980	**Research Assistant**, Department of Mineral Engineering, Columbia University, New York, NY. Laboratory instruction of extractive metal lurgy. Designed and built equipment for use in pyrometallurgical experiments.

<u>Engineering Appointments</u>

1985-Present	**President**, A_2Z Consultants, Inc., Chicago, IL. Consultant mainly in the application of mineral processing and extractive metallurgy to treatment of metal bearing wastes (both hazardous and nonhazardous) for metal recovery.
1980-1985	**Research Engineer,** Inland Steel Company, East Chicago, IN. Member of iron-bearing materials and refractories group of the raw materials and primary processing division, responsible for recovery of iron from iron-

bearing waste oxides with particular emphasis on treatment of materials containing zinc.

Education

	Columbia University, New York, NY
EngScD(1983)	Extractive Metallurgy and Mineral Engineering
MS (1975)	Extractive Metallurgy and Mineral Engineering
BS (1972)	Materials Science

Professional Honors:

Assocation for Iron and Steel Technology Foundation Grant Professor	2004-present
Iron and Steel Society Foundation Grant Professor,	2002-2004.
Frances Rhodes Prize – Columbia University,	1972.

Professional Memberships and Offices:

Iron and Steel Society (ISS)	
Education Committee/University Relations Committee	1990-present
Co-Chairman	1991-1995
Chairman Jerry Silver Award Committee	1992-1996
Research in Progress Session Chair	1988,1991,2001
Continuing Education Committee	1996-present
ASM, International	
Calumet Chapter	
Chairman	1992-1993,2001-2002
Vice Chairman	1991-1992,2000-2001
Chairman Education Committee	1988-1991
Board of Directors	1988-present
Institute of Briquetting and Agglomeration (IBA)	
Board of Directors	1987-present
Jerry Rice Award Committee	1993-present
Award for best paper at IBA Conference	
The Materials Society (TMS)	
American Society for Engineering Education (ASEE)	
Campus Representative	1994-1995
Sigma Xi	
American Foundry Society (AFS)	

Publications

Abramowitz, H., Bennett III, R.E**.,** Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W., "Load Testing of Temporary Structural Platforms," Proceedings of ASEE Annual Conference, Montreal, Canada, June 2002.

Abramowitz, H., Bennett III, R.E**.,** Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W., "Load Testing of Temporary Structural Platforms," National Educators' Workshop New:Update 2001 Standard Experiments in Engineering , Materials Science, and Technology, University of Maryland, College Park, MD, June, 2002, pp.413-434.

Bennett III, R.E, Abramowitz, H., Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W., "The Static and Dynamic Loading on Scaffolding Planks," Eighth International Conference on Composites, Tenerife, Spain, August 2001, pp. 75-76.

Abramowitz,H. "Mechanical Properties of Sheet Steels Used in Stamping and Drawing," National Educators' Workshop New:Update 99 Standard Experiments in Engineering, Materials Science, and Technology, Dearborn and Auburn Hills, MI, October 2000, pp.391-421.

Abramowitz,H. "Use of Piezoelectric Crystals for Voice Recognition," National Educators' Workshop New:Update 98 Standard Experiments in Engineering , Materials Science, and Technology, Brookhaven National Laboratory, NY, October, 1999, pp.379-392.

Kin,Y., Abramowitz,H., Hentea,T., Higley,J., and Richards,J., "Laboratory Measurement of J-Integral," National Educators' Workshop New:Update 98 Standard Experiments in Engineering , Materials Science, and Technology, Brookhaven National Laboratory, NY, October, 1999.

Kin,Y., Abramowitz,H., Hentea,T. and Xu,Y., "Life Estimate Based on Fatigue Crack Propagation," National Educators' Workshop New:Update 97 Standard Experiments in Engineering, Materials Science, and Technology, November, 1997, Seattle, WA, pp.369-380.

Kin,Y., Hentea,T., Abramowitz,H., and Xu,Y., "Theoretical and Experimental Investigation of Fatigue Crack Propagation in Laminates for Aircraft Canopies," Fourth International Conference on Composites Engineering, July, 1997, Hawaii, pp.537-538.

Bennett III,R., Abramowitz,H., Wright,J. and Boynak,D., "Pull-out Depth of Composite Reinforcing Bars in Concrete," Fourth International Conference on Composites Engineering, July, 1997, Hawaii, p.176.

Abramowitz,H., Hentea,T., Kin,Y., and Xu,Y., "Fatigue Investigation of Polycarbonate Used for Aircraft Canopies," Proceedings of the Fourth International Colloquium on Aging of Materials and Methods for the Assessment of Lifetimes of Engineering Plant, Cape Town, South Africa, April, 1997, pp.309-317.

Abramowitz, H., Hamling, J.W., and Landreth, R.R., "Inland Fixation Process," Proceedings of the National Research & Development Conference on the Control of Hazardous Materials, sponsored by the Hazardous Materials Control Research Institute, Feb. 20-22, 1991, Anaheim, CA, pp.439-442.

Chen, Y., Ricketts, J., Hevezi, J., and Abramowitz, H., "Expert System for Blast Furnace Operation," Proceedings of the 3rd International Conference on Industrial & Engineering Applications of Artificial Intelligence & Expert Systems, Industrial and Engineering Applications/Artificial Intelligence Engineering-90, July 15-18, 1990, Charleston, SC, 8 pps.

Abramowitz, H. and Balajee, S.R., "Recycling of Zinc-Bearing Steelmaking Dust Through Micro-Pelletizing and Pot-Grate Sintering," Proceedings of the 20th Biennial Conference, Vol. 20, Institute of Briquetting and Agglomeration, Orlando, FL, September, 1987, pp.65-80.

Abramowitz, H., Gaffney, L. J. and Ziegert, W. L., "Taphole Mix Properties and Performance for the First Year of Operation on Inland's No. 7 Blast Furnace," Ironmaking Proceedings, Vol. 42, Iron and Steel Society of the American Institute of Mining, Materials, and Petroleum Engineers, 1983, pp.681-694.

Abramowitz, H. and Rao, Y. K., "Direct Reduction of Zinc Sulphide by Carbon and Lime," Transactions/Section C, Institution of Mining and Metallurgy, Sept. 1978, Vol. 87, pp. C180-188.

Abramowitz, H., Insinga, R. and Rao, Y. K., " Kinetics of Sulfur Dioxide with Carbon," Carbon, 1976, Vol. 14, pp.84-86.

Papers Recently Presented

Abramowitz, H.and Babbitt, M.R., "Fatigue Properties of Cryogenically Treated D2 Tool Steel," ASM International Heat Treating Conference, Indianapolis, IN September,.2003.

Abramowitz, H., Bennett III, R.E**.,** Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W., "Load Testing of Temporary Structural Platforms," ASEE Annual Conference, Montreal, Canada, June 2002.

Abramowitz, H., Bennett III, R.E., Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W., "Load Testing of Temporary Structural Platforms," " National Educators' Workshop New:Update 2001 Standard Experiments in Engineering , Materials Science, and Technology, University of Maryland, College Park, MD, October, 2001, Experiment No. 31.

Bennett III, R.E, Abramowitz, H., Bennett, J.H., Hendrickson, R.J., Koultourides, C., Kucharski, W., and Tredway, B.W. "The Static and Dynamic Loading on Scaffolding Planks," Eighth International Conference on Composites, Tenerife, Spain, August 2001.

Abramowitz,H. "Determination of Viscosity Using a Falling Sphere Viscometer," ASEE Annual Conference, Albuquerque, NM, June 2001; live demonstration.

Abramowitz,H., "Two Experiments in Materials Science," Scholarship of Teaching/Learning Celebrating the Diversity of Faculty Scholarship, PUC, Jan.30, 2001.

Bennett III, R.E. and Abramowitz, H., "The Static and Dynamic Loading on Scaffolding Planks," Scholarship of Application, Celebrating the Diversity of Faculty Scholarship, PUC, Jan.30, 2001.

Abramowitz,H., "Determination of Viscosity Using a Falling Sphere Viscometer," National Educators' Workshop New Update 2000 Standard Experiments in Engineering, Materials Science, and Technology, Kettering, OH, Oct./Nov. 2000

Abramowitz,H., Kruse,E., Milkosy,M., Schutt,J., Vander Zee, R., Zylstra,D., "Improvement in Cross Cylinder Wear of M4 and M42 Tool Steels by Cryogenic Treatment," ASM International Heat Treating Conference, St.Louis, MO, Oct.2000.

Abramowitz,H. "Mechanical Properties of Sheet Steels Used in Stamping and Drawing," ASEE Annual Conference, St. Louis, MO, June 2000.

Abramowitz,H. "Mechanical Properties of Sheet Steels Used in Stamping and Drawing," National Educators' Workshop New:Update 99 Standard Experiments in Engineering, Materials Science, and Technology, Dearborn and Auburn Hills, MI, November, 1999, Experiment #27.

Abramowitz,H. "Use of Piezoelectric Crystals for Voice Recognition," ASEE Conference,

Charlotte, NC, June, 1999.

Bennett III, R., Abramowitz, H., Wright,J. and Boynak, D., “Pull-out Depth of Composite Reinforcing Bars in Concrete,” Celebrating the Diversity of Faculty Scholarship, Purdue University Calumet, February, 1999.

Kin,Y., Abramowitz,H., Hentea,T., Higley,J., and Richards,J., “Laboratory Measurement of J-Integral,” National Educators’ Workshop New:Update 98 Standard Experiments in Engineering , Materials Science, and Technology, Brookhaven National Laboratory, NY, November, 1998, Experiment No. 10.

Recent Grants

Iron and Steel Society Foundation (now the Association of Iron and Steel Technology)
Ferrous Metallurgy Grant Program Professor 2002-2005
NSF CSEMS Program, PI for 2001-2003.
NSF CSEMS Program (2nd grant) PI for 2003-2007
Lilly Foundation, Purdue Retention Grant PI for 2001-2002.
21 st Century Grant for Blast Furnace Hearth Model - member of research team 2003-2004

CHENN QIAN ZHOU
PURDUE UNIVERSITY CALUMET

Chenn Zhou received her B.S. and M.S. in Power Engineering from the Najing University of Aerospace and Aeonautics. In 1991, She was awarded a Ph.D. in Mechanical Engineering from Carneigie Mellon University. She had three years of industrial experience before joining the PUC faculty in 1994. She is currently Professor of Mechanical Engineering and the Graduate Coordinator in the Department of Engineering.

Professor Zhou teaches undergraduate and graduate courses in the areas of CFD, combustion, air pollution control, fluid dynamics, and heat transfer. Her main research areas include multiphase raecting flow modeling, energy utilization as well as pollutant formation and control. She has collaborated with many experts from academia, research organizations, and industry and conducted a number of funded research projects. Since 1995, she has participated in several projects at Argonne National Lab. Her specialization in Computational Fluid Dynamics (CFD) has enabled her to help regional and national corporations for enhancing their economic standing in manufacturing. She has conducted a number of projects funded by federal and state government agencies and companies. In 2003, Dr. Zhou received a $1.29 million grant from the Indiana 21st Century Research and Technology Fund for developing a CFD modeling system for steel blast furnaces. She has published over 100 technical papers and received several awards including University Outstanding Teacher and Researcher in 1999 and Outstanding Northwest Indiana Researcher, Northwest Indiana Chapter of Sigma Xi in 2001. Recently, she was elected a Fellow of The American Society of Mechanical Engineers (ASME) International.

Selected Publications

• Chang, S.L. and C.Q. Zhou, “Combustion and Thermodynamics", Article Number NRGY 00087 in *Encyclopedia of Energy*, Elsevier, Volume 1. 2004

• Vernengo, S., R. Milanovic, C.Q. Zhou, P. Chaubal and D. Huang, “Computations of Liquid Flow and Heat Transfer in the Hearth of a Blast Furnace”, *IMECE2003-55504* , Proceedings of 2003 ASME International Mechanical Engineering Congress and Exposition, Washington, D.C., November 15-21, 2003

• Chang, S.L. and C.Q. Zhou, "Simulation of FCC Riser Multiphase Heat Transfer and Cracking Reactions", *Computational Mechanics*, 31, 519-532, 2003

• Chang, S.L., B. Golchert, C.Q. Zhou, and M. Petrick, “*An Investigation of the effects of Firing Patterns on Heat Transfer and NOx Formation in A Glass Furnace*,” Proceedings of the 35th National Heat Transfer Conference, NHTC2001-20235, Anaheim, Cal. (June 10-12, 2001).

• Chang, S.L., C.Q. Zhou, S.A. Lottes, and M. Petrick, “*Numerical Evaluation of Advanced Multi-stage FCC Units*,” HTD-Vol.367:69-78, International Mechanical Engineering Congress and Exposition, Orlando, FL (November 5-10, 2000).

• Chang, S.L., S.A. Lottes, and C.Q. Zhou, Computational Fluid Dynamics Applications, *Energy 2000: State of the Art*, Edited by P. Catania, Balaban Publishers, L’Aquila, Italy, pp.299-324 (2000).

• Su, K. and C.Q. Zhou, "Numerical Study of Spray Parametric Effects on Gas Turbine Combustion Performance", HTD-Vol. 364, Proceedings of the ASME Heat Transfer Division 2:345-354, International Mechanical Engineering Congress and Exposition, Nashville, TN, November, 1999

• Zhou, C.Q., L.G. Neal, R. Bolli, J. Haslbeck, and A. Chang, "Control of NO_x Emissions by NO_x Recycle Approach", *The 26th Symposium (International) on Combustion*, Vol. 2, pp2091-2098, Combustion Institute, 1996

• Zhou, Q. S.C. Yao, T. Russell and J. Boyle, "Flue Gas NO_x Reduction Using Ammonia Radical Injections", *Journal of Air Waste & Management Association*, Vol.42, No.9, pp.1193-1197, Sept., 1992.

• Zhou, Q. and S.C. Yao, "Group Modeling of Impacting Spray Dynamics", *International Journal of Heat and Mass Transfer,* Vol. 35, No.1, pp.121-129, January, 1992

Anita M. Katti
Department of Chemistry & Physics
Purdue University Calumet

(a) Professional Preparation

- University of Missouri-Columbia, BS Chemical Engineering- 1983
- University of Delaware-Newark, MS Chemical Engineering- 1984

- Yale University, MS Chemical Engineering- 1987
- University of Tennessee-Knoxville, Ph.D. Chemical Engineering- 1990
- Ciba Geigy (Industrial Post Doctorial Fellowship), Basel Switzerland- 1990-1991

(b) Appointments

- Purdue University Calumet, Department of Chemistry, Assistant Professor-Tenure Track 2005-present
- Virginia State University, Department of Chemistry, Assistant Professor-Tenure Track, 2004-2005
- Kennesaw State University, Department of Chemistry, Atlanta, GA
  Assistant Professor- Full Time on 9 month contract, 2003-2004
  Assistant Professor-Part Time, 2002-2003
- UCB Bioproducts, Atlanta,GA- Scientist III, 2001-2003
- FeRx Inc., Boulder, CO- Manager of Analytical Chemistry Group, 1999-2001
- NaPro BioTherapeutics, Boulder, CO- Sr. Scientist, 1997-2001
- Mallinckrodt, Inc, St. Louis, MO- Principal Scientist, 1991-1997
- EiChrom Inc., Scientist, Chicago, IL, 1991
- Ciba-Geigy, Basel, Switzerland, Post Doctoral Fellow, 1990-1991

(c) Publications

Five Most Relevant

G. Guiochon, A. Felinger, A.M. Katti, D. Shirazi, “Fundamentals of Preparative and Nonlinear Chromatography, 2nd Edition,” Elsevier, in press.

A.M. Katti in K. Valko (Editor), “Strategies for the Development of Process Chromatography as a Unit Operation for the Pharmaceutical Industry,” Handbook of Analytical Separations: Methods in Drug Synthesis and Purification, Elsevier, Amsterdam, 2002.

A.M. Katti and P. Jageland, “Development and Optimization of Industrial Scale Chromatography for use in Manufacturing, “ Analusis Magazine, 25(7) (1998) 24.

G. Guiochon, S.G. Shirazi and A. Katti, "Fundamentals of Preparative and Nonlinear Chromatography," Academic Press 1994, pgs 709.

A.M. Katti, P. Erlandsson and R. Däppen, "An Application of Preparative Liquid Chromatography for the Isolation of Enantiomers of a Benzodiazepinone Derivative," J. Chromatogr., 509 (1992) 127.

Five Other Publications

A.M. Katti and G. Guiochon, "Fundamentals of Non-Linear Chromatography: Prediction of Band Profiles and Band Separation," Adv. in Chromatogr.,Marcel-Dekker,31(1992)1.

P.S. Katti, A.M. Katti and H.D. Johnson, "Determination of Heat Exposure Effects on the Production of Bovine Plasma and Milk Catecholamines," J. of Chromatogr., 566 (1991) 29.

A.M. Katti, Y.-F. Maa and Cs. Horváth, "Protein Surface Area and Retention in Hydrophobic Interaction Chromatography," Chromatographia, 24 (1987) 646.

K. Valko, I. Fellegvari, A.M. Katti and L. Otvös, "Correlation of HPLC Retention Data of Triazines with the Inhibition of DHFR from L1210 Cells: Development of a New Adsorption Parameter in QSAR," J. Liq. Chromatogr., 11(4) (1988) 833.

A.M. Katti, C.W. Carlson and R. West, "The Ethylmethylcyclosilanes," J. Organometallic Chemistry, 271 (1984) 353.

(d) Synergistic Activities

1. Industrial Sponsorship: In the calendar year 2003, my 1st year transitioning from industry to academia, a collaboration was developed with Avera Pharmaceuticals to i) evaluate process chromatography as an alternative to liquid-liquid extraction as a means to purify their drug substance and ii) purify 4 impurities which are undesired bioproducts of their chemical process to make this drug substance. As a part-time assistant professor at KSU, a series of grants during 2003 lead to ~$120,000 of sponsored support. The Avera grant purchased an quartinary gradient HPLC with diode array detection, supplies as well as my entire salary, student wages ($10/hr) and indirects. Water's Corporation donated $12,000 of HPLC parts for this project. Three students requested work on this research in the Spring of 2003. Two students continued in the summer and in the fall. The students were required to work 20 hrs/week. In the Spring'2003, matching funds where obtained from the State of Georgia through the ETACT program for $12,000 to purchase a HP-1090 HPLC.

2. Industrial Sponsorship: In the Fall'03, a 2 semester grant was obtained from Water's corporation to study the column saturation capacity of peptides as a function of the mobile phase composition. Two students worked on this project for Directed Research course credit. In the Spring'04, a grant for $2,500 was approved by the College to support the Water's project for travel and supplies.

3. Student Presentations: During the year 2003, two students made oral presentations at the Southern Undergraduate Research Conference. One student was congratulated as best speaker. The students presented four different posters. A student was funded to travel out of state by these grants to present and assist in conference operations at the PREP'03 and another student at the PREP'04 conference. In addition, the students presented at the Southeastern Regional American Chemical Society Meeting and at the KSU internal Scholar's Program. This summer I plan to write two publications in referred journals on this research.

4. e-Teaching: In the Spring of 2003, I was one of four professors in the College of Sciences who evaluated the "Personal Response System" as an electronic teaching tool to enhance interactive learning in the classroom for students in general chemistry, and quantitative analysis laboratory. The student feedback was excellent in quantitative analysis laboratory, 20 students, where chemistry students struggle to understand the laboratory experiment prior to performing it and to comprehend the meaning of the results after submitting a formal laboratory report. In General Chemistry, a class of 60-70 students, lecture attendance increased as well as the number of scientific questions asked. In addition, use of BLACKBOARD, WEB-CT and OWL-THOMPSON LEARNING supplemented classroom learning. In the quantitative analysis laboratory course at VSU and KSU, e-instruction enabled the students to shared data on-line for inter- and intra-student evaluation of precision, accuracy and robustness. Statistical methods and scientific methodologies were similar to those used to meet the Food and Drug Administration compliance requirements for the validation of analytical methods in the pharmaceutical and biotechnology industry. The students at VSU, a Historically Black College University, benefit from these e-learning innovations. The VSU students include chemistry majors taking analytical chemistry, engineering, biology and other science majors taking general chemistry as well as students requiring general education chemistry benefit from supplemental e-instruction. In the Fall'04, I could impact ~127 different undergraduate students. The use of industrial experiences assists students to bring chemistry alive in their minds. It is often a challenge to spark a freshman's interest in the abstract concepts of chemistry. However, by allowing them to see the chemistry around them through industrial examples, curiosity seems to sprout and memory appeared enhanced.

5. Professional Maintenance: I have been an active member of the Scientific Committee for the PREP series of meetings for ~10 years. I have chaired sessions at the AICHE meetings in 2004 and 2002. I was invited to speak at the HPLC'04 meeting in Philadelphia. I have spent the last 1.5 years working on the 2nd edition to our book on Preparative and Nonlinear Chromatography.

(e) Collaborators & Other Affiliations

- Collaborators
  - Prof. Georges Guiochon, University of Tennessee, Knoxville, TN
  - Mr. Richard Johnson, Avera Pharmaceutials, San Diego, CA
  - Dr. Huggins Msimanga, Kennesaw State University, Atlanta, GA
  - Dr. Uwe Neue, Water's Corporation, Milford, CT
- Former Undergraduate Directed Research Students
  - Ms. Jennifer Carpenter, United Research Laboratories/Mutual Pharmaceutical
  - Mr. Taylor Evers, AtheroGenics, Inc., Atlanta, GA
  - Ms. A. Rachel Prakash, Pursuing Certificate for Master Gardener
  - Mr. Patrick Shaw, Kennesaw, GA (Applying for PhD programs for Fall'05)
  - Ms. Caroline St. Antoine, Self Employed in Family Medical Transcription Company

Graduate Advisors:

Ph.D.: Professor Georges Guiochon, University of Tennessee-Knoxville, Department of Chemistry
MS: Late Professor Csaba Horvath, Yale University, Department of Chemical Engineering
MS: Dr. R. Secor, Retired DuPont Experimental Station and Late Prof. R. Pigford, University of Delaware.
Thesis Advisors & Current Support: No graduate students. No current or pending grants.

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EDUCATION:
Ph.D. Geology, Boston University, Boston, Massachusetts, 1976
M.A. Geology, Bryn Mawr College, Bryn Mawr, Pennsylvania, 1972
M.Sc. (Tech.) Applied Geology, Nagpur University, Nagpur, India, 1968
EXPERIENCE:
Current: Consultant to steel mills, coal companies and coke plants in USA., China, India, and various other countries around the world.
September 1979-June 2002: Staff Scientist, Ispat Inland Inc. (earlier Inland Steel Company), R & D Laboratories, East Chicago, IN, USA.
August 1978-May 1979: Assistant Professor, Geology Dept., Oberlin College, Oberlin, Ohio.
January 1978-May 1978: Visiting Assistant Professor, Geology Dept., Case Western Reserve University, Cleveland, Ohio.
May 1976—November 1977: Post Doctoral Fellow, Boston University, Boston, Massachusetts.
EXPERTISE:
Blend designs for non-recovery and slot oven cokemaking; Research on carbonization behavior of coal in non-recovery and slot oven cokemaking; Prediction of coke quality for non-recovery and slot oven cokemaking; Extensive knowledge of Chinese nonrecovery
and slot oven plants; Modification of Chinese beehive cokes for blast furnace usability; Use of reverts in cokemaking, ironmaking, and steelmaking; Research in understanding coke behavior in blast furnace through tuyere coke sampling; Coal behavior in blast furnace pulverized coal injection; Coal selection for PCI.
AWARDS AND HONORS:
Iron and Steel Society's Joseph Becker Award, 1999, ("Distinguished Contributions in the Field of Coal Carbonization and Coal Technology").
American Iron and Steel Institute President Medal, 1989, ("Outstanding Paper Published

in 1988-1989”).
Eminent Visitor Program – sponsored by CCSD/CSIRO, Australia, Feb. 10, 2003- Feb. 21, 2003.
Key Note Lecture, 2001, 3rd Ironmaking Conference, Instituto Argentino De Siderurgio, Buenos Aires.
Organized a special three part session entitled “Use of Coal in the Steel Industry” at the 11 th Annual Pittsburgh Coal Conference, Pittsburgh, PA, September 12-16, 1994; followed by a special two part session on “Coal Use in Steel Industry” for the13th Annual Pittsburgh Coal Conference, Pittsburgh, PA, September 3-7, 1996.
Sigma Xi – The Scientific Research Society of North America (National Research Honor Society) Grant Award, 1975.
Gold Medal, 1966, Nagpur University, Nagpur, India.
American Men and Women of Science.

TECHNICAL COMMITTEES:

Program Committee Member, Ironmaking Divison, Iron and Steel Society, 1995-present.
Joseph Becker Award Committee Chairman, Iron and Steel Society, 2001-present.
American Iron and Steel Institute Technical Committee on Coke Oven Practice Member, 1995-2001.
American Iron and Steel Institute Tall Oven Task Group Member, 1988-1990.
McMaster University, Coordinating Committee Member, Cokemaking Course, 1999.
McMaster University, Coordinating Committee Member, Cokemaking Course, 1997.
American Iron and Steel Institute Direct Steelmaking Process Consultant, Coal Selection, 1989.

TECHNICAL SESSIONS CHAIRED:

19)Valia, H. and Best, M., Cokemaking, ISSTech 2003, ISS Conference, Indianapolis, IN, April 28, 2003.
18)Valia, H. and Best, M., Special Session on Coal, ISS Ironmaking Conference, Nashville, TN, March 11, 2002.
17)Valia, H. and Williams, H., Coal Market & The Steel Industry, ISS Ironmaking, Conference Baltimore, MD, March 27, 2001.
16)Valia, H. and Ellis, C., Coal & Coke Research, ISS Ironmaking Conference, Pittsburgh, PA, March 27, 2001.
15)Sciazko, M. and Valia, H., Cokemaking Environmental Control, 4th European Coke and Ironmaking Congress, ATS, Paris, France, June 21, 2001, AM Session.
14)Valia, H., Intensive Course on Cokemaking, McMaster University, Hamilton, Canada, May 11, 1999, AM Session.
13)Valia, H. and Cheng, A., Alternative Cokemaking-Non Recovery Cokemaking, ISS Ironmaking Conference, Chicago, IL, March 22, 1999.
12)Valia, H. and Hinds, S., Coke Oven and Coke Quality Modeling, ISS Ironmaking Conference, Toronto, Canada, March 24, 1998.
11)Valia, H., Intensive Course on Cokemaking, McMaster University, Hamilton, Canada, May 13, 1997, AM Session.
10)Valia, H. and Flynn, K., Cokemaking Research, ISS Ironmaking Conference, Chicago, IL., April 15, 1997.
9)Valia, H., Nashan, G., Oreskovic, and Bristow, N., Executive Business Forum, Coping with the Tightening Coke Supply, Gorham/Intertech Conf., Charlotte, N.C., March 7,

1998.
8)Westman R. and Valia, H., Coal Use in Steel Industry-COREX, 13th Annual International Pittsburgh Coal Conference, Pittsburgh, PA., September 3-7, 1996.
7)Poveromo J. and Valia, H., Coal Use in Steel Industry-PCI , 13th Annual International Pittsburgh Coal Conference, Pittsburgh, PA., September 3-7, 1996.
6)Valia, H. and Readyhough, P., Cokemaking Battery Heating, ISS Ironmaking Conference, Pittsburgh, PA., March 26, 1996.
5)Valia, H. and Thompson, R., Use of Coal in the Steel Industry-I, 11th Annual International Pittsburgh Coal Conference, Pittsburgh, September 14, 1994.
4)Valia, H. and Thompson, R., Use of Coal in the Steel Industry-II, 11th Annual International Pittsburgh Coal Conference, Pittsburgh, September 14, 1994.
3)Valia, H, Round Table Participant at the National Seminar on Coal for Blast Furnace Coke and for Injection, Indian Institute of Metals and Tata Steel, Jamshedpur, India, September 22, 1990.
2)Valia, H., 5th Annual Meeting of the Society for Organic Petrology, Houston, TX, Nov. 7, 1988, AM Session.
1)Valia, H. and Byers, C., Geological Society of America-North Central Section, 13th annual Mtg, Duluth, MN, May 10-11, 1979.

SHORT COURSES TAUGHT:

2004 – Global Coking Coal Quality & Importance during Met Coke Crisis, INTERTECH
2003 – Cokemaking Course, McMaster University
1999 - Coke Production, Blast Furnace Ironmaking, McMaster University
1999 – Cokemaking Course, McMaster University
1998 - Coke Production, Blast Furnace Ironmaking, McMaster University
1997 – Cokemaking Course, McMaster University
1997 - Coal Selection, Iron & Steel Society, Continuing Education.
1996 - Coke Production, Blast Furnace Ironmaking, McMaster University
1996 - Coal Selection, Iron & Steel Society, Continuing Education.
1994 - Coke Production, Blast Furnace Ironmaking, McMaster University

PUBLICATIONS:

66)WEB Site of American Iron & Steel Institute – www.steel.org , Learning Center, How Steel is made, Coke Production for Blast Furnace Ironmaking, Date – Current.
65) Valia, H.S., Yan Jiying, and Song Weijie, “Production of Super Strength Coke from Non-Recovery Cokemaking at Shanxi Sanjia, Jixiu, Shanxi Province, China,” AISTech 2004 Proceedings, Volume 1, p. 633-636.
64) Valia, H.S., “Bright Future for the World Non Recovery/Heat Recovery Technology,” Proceedings of Global Steel 2004, January 2004, Bombay, India.
63)Valia, H.S., “Global Coking Coal Quality and Importance during Met Coke Crisis,” Short Course Pre-Conference Proc., Intertech World Met Coke Summit, October, 2004, Chicago, USA.
62) Agarwalla, Asim, Agarwalla, Anup, and Valia, H.S., “High Quality Coke from Non Recovery BLA Coke Plant, Mithapur, India,” Proc. Intertech World Met Coke Summit October, 2004.
61)Valia, H.S. and M. Mastalerz, “Indiana Coals and the Steel Industry,” Indiana Geological Survey Special Report Number 64, Bloomington, Indiana, 2004, 28 pp.
60)Chaubal, P.C. and Valia, H.S., “Behavior of Stamped Non Recovery Coke in B.F.,”

METEC Congress 2003, Dusseldorf, Germany.
59)Valia, H.S., “Coke Production Utilizing Non Recovery/Heat Recovery Technology,” McMaster Cokemaking Course, Hamilton, Canada, 2003, pp.
58)Kruse, R.J., Chaubal, P.C., Moore, J.B., and Valia, H., “Blast Furnace PCI Coal Selection at Ispat Inland,” ISS Ironmaking Proc., Vol., 2003, pp.
57)Valia, H.S. and Mastalerz, M., “Indiana Coals and the Steel Industry,” ISS Ironmaking Proc., Vol., 2003, pp.
56)Valia, H.S., “Coke Production, Coal Selection, and Coal Quality Monitoring,” Keystone Coal Manual, 2003, pp.
55)Valia, H.S., “Journey of a Coal from a Coal Seam to the Hearth of a Blast Furnace,” Intertech Con. On “Coke at the Crossroads 2002,” St. Louis, Missouri, pp.
54)Valia, H.S., “Coal Blend Rank Changes and Resultant Coke Quality from IHCC Heat Recovery Cokemaking,” Am. Iron & Steel Engineers, Annual Conf. Proceedings, 2002.
53)Valia, H.S., “Coal Blend Rank Changes and Resultant Coke Quality from IHCC Heat Recovery Cokemaking,” ISS-Ironmaking Proc., Vol. 61, 2002, pp. 419-426; Iron & Steelmaker, December 2002, pp. 43-47.
52)Best, M., Burgo, J., and Valia, H., “Effect of Coke Strength After Reaction (CSR) on Blast Furnace Performance,” ISS-Ironmaking Proc., Vol. 61, 2002, pp. 213-239.
51)Valia, H.S., “Coke Breakage Behavior of Heat recovery Coke,” 3 rd Ironmaking Seminar, Instituto Argentino de Diderurgia, Oct. 29-Nov. 1, 2001, Buenos Aires, Argentina, pp. 11-14.
50)Valia, H.S., “Coke Quality from Coke Plants Utilizing Three different Production Methods,” 1st International Mtg on Ironmaking, Brazilian Assoc. for Metallurgy (ABM), Sept. 24-26, 2001, Belo Horizonte, Brazil, pp. 105-115.
49)Duttler, M., Carter, W., Chaubal, P., Knorr, E., Moore, J., Valia, H., and Zuke, D., “Experience with Heat Recovery Coke Use at Ispat Inland No. 7 B.F., “ ISS-Ironmaking Conference Proc., Vol. 60, 2001, pp. 129-139.
48)Valia, H., “The Comparison of Coke Quality from a By-Product (USA), A Non-Recovery (China), and Heat Recovery Coke Plant (USA), “ 4th European Cokemaking and Ironmaking Congress, 2000, Paris, p. 148-156.
47)Knorr, E., Carter, W., Chaubal, P., Moore, J., Ranade, M., Valia, H., and Zuke, D., “Transition of Ispat Inland’s No. 7 B.F. from conventional to Heat Recovery Coke,” 4th European Cokemaking and Ironmaking Congress, 2000, Paris, pp. 148-156.
46)Sahajwalla, V., Kong, C.H., Chaubal, P., and Valia, H., “Determination of Proportions of Coal Char and Coke Fines in the Off Gas Blast Furnace Samples,” ISSIronmaking
Conference Proc., Vol. 59, 2000, pp. 129-139.
45)Valia, H.S., “Coals for Metallurgical Coke Production,” Chapter 7.2 in Making, Shaping, and Treating of Steel, Edited by Wakelin, D.H.,11th Edition, Ironmaking Volume, The AISE Steel Foundation, Pittsburgh, pp. 384-395.
44)Ellis, A.R., Schuett, K.J., Thorley, T., and Valia, H., “Heat Recovery Cokemaking at Indiana Harbor Coke Company – An Historic Event for the Steel Industry,” ISSIronmaking
Conference Proc., Vol. 58, 1999, pp. 129-139.
43)Lu, W.K. and Valia, H.S., “Analysis of Some New Ironmaking and Cokemaking Processes with Respect to Environment Protection,” International Symposium on Global

Environment and Iron and Steel Industry, Chinese Society of Metals and United Nations Environment Program, April 14-16, 1998, Beijing, China, pp. 185-190.
42)Valia, H.S., “Coke Quality from the Current and Future Coke Producing Technologies,” Coping with the Tightening Coke Supply, “ Gorham/Intertech Conference, March 5-7, 1997, Charlotte, N.C.
41)Valia, H.S., “Design of Coal Blends for required Coke Properties,” Intensive Course on Cokemaking, McMaster University, May 13, 1997, Vol. I, Raw Materials.
40)Chaubal, P., White D., and Valia, H., “Development of Coal Injection at Inland steel,” American Iron & Steel Engineers-Blast Furnace Injection Symposium, Cleveland, 1996, pp. 47-58.
39)Valia, H.S., “Blending Coal for Cokemaking,” in Selecting Coals for Quality Coke, Iron & Steel Society 1996 Ironmaking Short Course, Pittsburgh, PA., March 24, 1996, pp. 208-258.
38)Valia, “Hands on Examples of Blending Coal and Quality Control of Coals,” in Selecting Coals for Quality Coke, Iron & Steel Society 1996 Ironmaking Short Course, Pittsburgh, PA., March 24, 1996, pp. 259-268.
37)Valia, H.S., “Coke Production for Blast Furnace Ironmaking,” Blast Furnace Ironmaking Short Course, Vol. 1 - Principles, Design, and Raw Materials, Mcmaster university, May 1996, pp. 10-1 to 10-19.
36)Valia, H.S., “Coal Usage in the Steel Industry,” in ASIA Coal 1995 Conference, Singapore, March 20-22, 1995.
35)Valia, H.S. and Harrison, C.H., “Improvement in Coke Carbon Form through Induction Heating,” FUEL, 1994, Vol. 73, No. 6, pp. 962-966.
34)Valia, H.S. and Hooper, W., “Use of Reverts and Non-Coking Coals in Metallurgical Cokemaking,” ISS-Ironmaking Conference Proc., Vol. 53, 1994, pp. 129-139.
33)Hurt, R., Davis, K., Yang, N., Gibbins, J., and Valia, H., “Carbon Burnout in Pulverized Coal Combustion: An Overview of Mechanism and Trends,” The Effects of Coal Quality on Power Plants, 4th International Conference, Electric Power Research Institute, Aug. 17-19, 1994, Charleston, S.C.
32)Valia, H., “Coke Production for B.F. Ironmaking,” An Intensive Short Course in B.F. Ironmaking, Vol. 2, Raw Materials, May 1994, McMaster University.
31)Valia, H.S., “Coal Quality Reserve Evaluation for the Iron and Steel Industry,” Proc. 10th Annual International Pittsburgh Coal Conference, Sept. 20-24, 1993, Pittsburgh, PA., pp. 305-310.
30)Kaegi, D., Addes, V., Valia, H., and Grant, M., “Carbonization” Chapter in “Coal Conversion Process,” Kirk-Othmer Encyclopedia of Chemical Technology, 4th Edition, Vol. 6, John Wiley & Sons, pp. 489-511.
29)Valia, H.S., “Coal and Petroleum Coke Interactions during Carbonization,” ISSIronmaking
Conference Proc., Vol. 51, 1992, pp. 435-447.
28)Valia, H.S. and Harrison, C.H., “Improvement in Coke Carbon Form through Induction Heating,” Paper presented at the 2nd International Symp. on Structure, Properties, and Reactivity of Coal, Polish Academy of Sciences and CNRS of France, Krakow, Poland, Sept. 21-23,1992.
27)Valia, H.S., “Effects of Coal Oxidation on Cokemaking,” ISS-Ironmaking Conference Proc., Vol. 49, 1990, pp. 199-209.

26)Valia, H.S., “Predicting Coke Strength After Reaction with CO2 from Coal Analysis,” in “Coke Reactivity and It’s effect on Blast Furnace Operation,” Edited by Gray, R.J. and Goscinski, J., 1990, Iron & Steel Society Publication, pp. 109-119.
25)Valia, H.S., Kaegi, D., Addes, V.I., and Zuke D.A., “Production and Use of High CSR Coke at Inland Steel Company,” in “Coke Reactivity and It’s effect on Blast Furnace Operation,” Edited by Gray, R.J. and Goscinski, J., 1990, Iron & Steel Society Publication, pp. 59-72.
24)Valia, H.S., “Prediction of Coke Strength After Reaction with CO2 from Coal Analysis at Inland Steel Company,” Transactions of the ISS, Vol. 11, 190, pp. 55-65.
23)Valia, H.S., “Prediction of Coke Strength After Reaction with CO2 from Coal analysis at Inland Steel Company,” Iron and Steelmaker, May 1989, pp. 77-87.
22)Valia, H.S., Kaegi, D., Addes, V.I., and Zuke D.A., “Production and Use of High CSR Coke at Inland Steel Company,” ISS-Ironmaking Conference Proc., Vol. 48, 1989, pp. 133-146.
21)Kaegi, D., Valia, H. and Harrison, C., “Maceral Behavior and Coal Carbonization,” ISS-Ironmaking Conference Proc., Vol. 47, 1988, pp. 339-349.
20)Kaegi, D.D. and Valia, H.S., “Coke Carbon Form Analysis as a Means for understanding Maceral Behavior and Coal carbonization, ” The Society for Organic Petrology, 3rd Annual Mtg Abstracts, 1986.
19)Valia, H.S. and Kaegi, D.D., “The Influence of Exudatinite on the Carbonization Behavior of a Medium Volatile Coal from Colorado,” Geological Society of America 97th Annual Mtg. Symposium – “Characterization of Western Coals,” Reno, Nevada, 1984.
18)Valia, H.S. and Spearin, E.Y., “The Fluorescent and Infrared analysis of Solvent Induced Reaction Product of Coal,” 16th Biennial Conference on Carbon, Extended Abstracts, American Carbon Society, July 18-22, 1983, san Diego, CA, pp. 449-450.
17)Valia, H.S., “Petrography and Possible Future Utilization of the Pennsylvanian Middle Kittanning (No. 6) Coal, Ohi0,” 9th International Congress of Carboniferous Strat. & Geol. Abstracts, 1979, p. 221.
16)Valia, H.S., “Surface Microtextures of Detrital Garnet Grains,” Geol. Soc. America, Abs., Vol. 11, No. 5, 1979, p. 259.
15)Valia, H.S. and Jones, R., “A Petrographic and Factor Analysis of Maceral Variables in Coal seam No. 3 Kamptee, Maharastra, India,” Tenth International Congress on Sedimentology, Jerusalem, Israel, Abs., Vol. 2, 1978, p. 698.
14)Valia, H.S. and Cameron, B., “Skewness as a Paeoenvironmental Indicator,” Reply: Journal of Sedimentary Petrology, Vol. 48, 1978, pp. 1002-1004.
13)Valia, H.S., Cameron, B., and Khalifa, H., “Recorrelation of Eocene-Miocene Boundary of Delaware Coastal Plain,” Reply: American Assoc. of Petroleum Geologists Bulletin, Vol. 62, 1978, pp. 1715-1717.
12)Valia, H.S., “Distinction of Paleoshoreline Environments Through Scanning Electron Microscopy and Lithology,” Geol. Soc. America, Abs., Vol. 10, No. 2, 1978, p. 90.
11)Valia, H.S. and Cameron, B., “Paleoenvironmental Analysis of the Chesapeake Group (Miocene) of the Delaware Coastal Plain,” Geol. Soc. America, Abs., Vol. 9, No. 3, 1977, p. 326.
10)Valia, H.S., “Petrographic Study of Coal from the Rhode Island Formation, Narragansett Basin, New England – Part I, ” Open File Report, Weston Observatory,

Boston College, Boston, 1977.
9)Valia, H.S. and Cameron, B., “Skewness as a Paleoenvironmental Indicator,” Journal of Sedimentary Petrology, Vol. 47, 1977, pp. 784-793.
8)Valia, H.S., Cameron, B., and Khalifa, H., “Recorrelation of Eocene-Miocene Boundary of the Delaware Coastal Plain,” Reply: American Assoc. of Petroleum Geologists Bulletin, Vol. 61, No. 5, 1977, pp. 723-727.
7)Valia, H.S. and Cameron, B., “Miocene Transgressions and Regressions of Delaware Coastal Plain,” American assoc. of Petroleum Geologists Bulletin, Vol. 60, pp. 784-785.
6)Valia, H.S. and Cameron, B., “Use of Skewness as a Paleoenvironmental Indicator,” Geol. Soc. America, Abs., Vol. 8, No. 2, 1976, p. 291.
5)Valia, H.S., “Petrology and Stratigraphy of the Uppermost Miocene Sediments of Central Delaware,” Geol. Soc. America, Abs., Vol. 7, No. 1, 1975, p. 122.
4)Valia, H.S., “Petrographic Study of Miocene Sediments of Central Delaware and Southern New Jersey,” Open File Report, Academy of Natural Sciences, Philadelphia, 1975, p. 51.
3)Valia, H.S., “Miocene Sedimentation and Stratigraphy of the Delaware Coastal Plain,” Ph.D. Thesis, Boston University, Dissertation Abstracts International, 1976.
2)Valia, H.S., “Ground water Provinces of India,” Bhuvigyan, Vol. 2, No. 1, 1970, pp. 51-53.
1)Valia, H.S., “Inside the Earth” – A book in Hindi for Young Adults, Visva Bharti Publications, Nagpur, India, 1969, 26 p.

Libbie S. W. Pelter
Assistant Professor, Chemistry
Purdue University Calumet

Education:
Ph.D. Organic Chemistry, University of California at Berkeley
Research Advisor: Dr. K. Peter C. Vollhardt.

Recent Appointments:
2005-Summer University of Nebraska-Lincoln
Research Assistant Professor of Chemistry, Department of Chemistry
- Collaboration with Professor James Takacs

2003-Present Purdue University Calumet
Assistant Professor of Chemistry, Department of Chemistry and Physics.
- Director, Undergraduate Research Program (8/03-5/05)

2001-2003 Purdue University Calumet
Professional Development Specialist, School of Engineering, Mathematics and Sciences
- Assistant Dean (1/03-7/03)
- Coordinator, Undergraduate Research Program
- 0.25 FTE Department of Chemistry

1999–August 2000 Center for Nanoscale Science and Technology Rice University
Research Scientist/Postdoctoral Fellow

- Research Director: Dr. James M. Tour
- Preparative combinatorial routes to thousands of precise conjugated oligomers

Research Interests:

Development and evaluation of transition metal catalysts useful in carbon-carbon bond forming reactions with improved TON and TOF. Solid-phase organic synthesis and metal mediated carbon-carbon bond forming reactions for the synthesis of conjugated oligomers. These highly conjugated organic molecules are of interest in molecular electronic applications and the construction of nanoarchitectures. Organic synthesis using microwave heating.

Selected Publications and Presentations:

Takacs, J. M.;* Venkataraman, S.; Andrews, R. N., "N-Heterocyclic Carbene–Palladium Catalysts for the Bisdiene Cyclization-Trapping reaction with Sulfonamides under Thermal and Microwave Conditions," *J. Organomet. Chem*., accepted 31 August 2005 (available on line)

Michael W. Pelter, Libbie S. W. Pelter, Dusanka Colovic, Regina Strug, "The Microscale Synthesis of 1-Bromo-3-chloro-5-iodobenzene: An Improved Deamination of 2-Chloro-4-bromo-6-iodoaniline," *J. Chem. Ed*., **2004**, *81*, 111.

J. M. Takacs and L. Pelter, "Formation of C-C Bonds by Electrocyclic Reactions", in Houben-Weyl Stereoselective Synthesis E 21; G. Helmchen, F. W. Hoffman, J. Mulzer and E. Schaumann, ed.; Georg Thieme Verlag: New York, 1995; Vol. E 21 d; pp. 3833-49.

Libbie S. W. Pelter*, Brian Heiberger, Solomon Brown, and Michael W. Pelter*, "Synthesis and coupling of halogenated benzene compounds useful in the construction of nanoelectronic components", Presented at the 230th ACS National Meeting, Washington, D.C., Aug.-Sept. 2005.

Kenneth R. Berg (Dr. Libbie Pelter), "Suzuki Couplings for the Synthesis of Nanoscale structures with Applications in Molecular Electronics" NCUR 2004: 18th National Conference on Undergraduate Research, Indianapolis, IN, April 15-17, 2004.

Regina J. Strug, Ken R. Berg, Amy S. Gorcowski, Stacy L. Snyder, and Solomon E. Brown (Dr. Libbie Pelter, Dr. Michael Pelter), "Combinatorial Approach to Organic Synthesis of Nanoelectronic Components" NCUR 2004: 18th National Conference on Undergraduate Research, Indianapolis, IN, April 15-17, 2004.

M.W. Pelter*, L.S.W. Pelter*, R. Strug, K. Berg, A. Gorcowski, "Combinatorial Screening of Reagents and Catalysts in Homogeneous Metal Mediated Cross-Coupling Reactions" National Organic Symposium, American Chemical Society, Bloomington, IN, June, 2003.

References

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[3] Smith, V., "Russian Steelmaker Buys Into Coke Ovens,**"** www.Nwitimes.com, 12/28/2004.
[4] Valia, H., "Coke Production for Blast Furnace Ironmaking", American Iron and Steel Institute.
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[6] SunCoke Company, Knoxville, Tennessee, http://www.suncoke.com.
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[9] Mastalerz, M., Drobniak, A., Rupp, J., Shaffer, N., "Characterization of Indiana's Coal Resource: Availability of the Reserves, Physical and Chemical Properties of the coal, and the Present and Potential Uses," Indiana Geological Survey Open-File Study 04-02.
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