

FINAL TECHNICAL REPORT
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Project Title: **STATE OF ILLINOIS 2006 PARTICIPATION IN COAL FUELS ALLIANCE**

ICCI Project Number: DEV05-5
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ABSTRACT

By the authority provided in Section 417 of the Federal Energy Policy Act of 2005, the current work was undertaken as a part of the initiative to promote the use of Illinois basin coals for production of liquid transportation fuels by Fischer-Tropsch (FT) type processes. An alliance (the Illinois Basin Coal Fuel Alliance – CFA) has been established between the three institutions named in the legislation (SIU, Purdue, and UK CAER) and a Memorandum of Understanding has been co-signed by all participants. The work mainly consisted of SIU participation in the efforts of the CFA.

The following activities were conducted and completed by the funds available for this project:

1. CFA planning and coordination activities.
2. Preparation of reports, documents, and proposals required by the Energy Policy Act and responsible federal agencies.
3. Design and specification of SIU FT Laboratory facilities necessary for participation in the effort mandated by the legislation.
4. Acquisition of some equipment –analytical and process.
5. Organization of a symposium on state of the art FT technology and technology development needs.

EXECUTIVE SUMMARY

The objective of this project was to enable and enhance the degree of participation of the State of Illinois (in particular Southern Illinois University) in the Illinois Basin Coal Fuel Alliance (CFA) that was established between Purdue University Energy Center, the Southern Illinois University Coal Research Center and the University of Kentucky Center for Applied Energy Research under the authority provisioned in Section 417 of the Federal Energy Policy Act of 2005 (Energy Policy Act). This act authorizes an initiative to promote the use of Illinois basin coals for production of liquid transportation fuels by Fischer-Tropsch (FT) type processes. The act specifies that this initiative is to be carried out jointly between the Purdue University Energy Center, the Southern Illinois University Coal Research Center, and the University of Kentucky Center for Applied Energy Research. The act authorizes (but does not appropriate) federal funding for this purpose. A Memorandum of Understanding has been co-signed by the three institutions.

In order to enhance the State of Illinois' participation through SIU in the efforts of the CFA, the following objectives were achieved to facilitate Illinois' ability to leverage future federal support under the provisions of the Energy Policy Act:

- (i) Facilitation of CFA participation with the DOE in preparation of reports required by the Energy Policy Act.
- (ii) Participation (with other CFA members) in planning and organizational activities.
- (iii) Collaboration with DOE for program development.
- (iv) Hiring of support personnel (post doc or researcher) for preliminary studies as described under phase I of the proposed (Federal) program.
- (v) Design and specification of state-of the art modular, flexible FT laboratory facilities for use in CFA-associated FT studies.
- (vi) Acquisition of necessary laboratory and process equipment.
- (vii) Organization of a symposium, held in conjunction with the conference hosted by the American Chemical Society, to summarize the current state-of-the-art and identify technology implementation barriers.

Task 1. Staff/Support staff /Graduate Students

One researcher and two graduate students were hired along with temporary support staff to conduct preliminary experiments.

Task 2. Facilities design and specification

The flexible, modular I-lab was designed. It consists of three sections, namely the catalyst preparation, FT synthesis, and product characterization. The FT synthesis section was also designed to house several reactors that were modular in design. Several reactors were designed and 1 reactor system has been acquired with the funds available.

Task 3. Travel and communications

The objective of this task was to support travel for CFA activities as well as achieve the objectives listed for this project. Several meetings were held by the CFA partners and attended by SIU faculty and administration. In addition, the PIs also attended conferences geared towards FT process and coal to liquids processes and held one-on-one meetings with some of the experts in this field.

Task 4. Symposium

A symposium was arranged by the PIs to be held in conjunction with American Chemical Society's annual conference to discuss the state of the art of FT synthesis, the opportunities and barriers towards the implantation of this technology, and future research needs.

RESULTS

A researcher was hired after an extensive search process. In addition, two graduate students were hired for conducting research on FT synthesis. The graduate students will be completing their thesis work in this field. In addition, support staff were hired on a temporary basis to aid in the experiments and some preliminary setup. The PIs attended the meetings held with the CFA partners. In addition, the PIs also attended the meetings held by the local American Institute of Chemical Engineers meeting that focused on FT process development and other important conferences in this research area. In addition, the PIs held meeting with GTI both in Carbondale and in Chicago to discuss opportunities for synergistic collaborations. A symposium was held with the leadership of the PIs as a part of the ACS's annual conference that discussed the present state of art of the FT synthesis process, the opportunities and the barriers towards implementation, and future research needs. The flexible I-lab concept was designed. Some necessary laboratory equipment, such as a GC, and process equipment, such as a 2 feet tall, high-pressure reactor system, were acquired.

OBJECTIVES

The recent run up in crude oil prices and damage to the domestic refining system have demonstrated the vulnerability of US liquid transportation fuel supplies to disruption. It is, therefore, desirable for strategic and economic reasons to develop secure, domestic resources for the production of these fuels. Section 417 of the Federal Energy Policy Act of 2005 (Energy Policy Act), authorizes an initiative to promote the use of Illinois basin coals for production of a secure domestic supply of liquid transportation fuels by Fischer-Tropsch (FT) type processes. The legislation specifies that this initiative is to be carried out jointly between the Purdue University Energy Center, the Southern Illinois University Coal Research Center, and the University of Kentucky Center for Applied Energy Research under the auspices and oversight of the Department of Energy (DOE). An alliance, known as the Coal Fuels Alliance (CFA) has been established between the organizations named in the Energy Policy Act to facilitate completion of the objectives of the legislation and a Memorandum of Understanding between the member organizations has been signed.

A preliminary, three-phase work plan for achieving the objectives of the Energy Policy Act has been developed (and continues to be refined). This plan will be carried out jointly by all CFA participants primarily using federal monies once these are appropriated. In the short term, the objectives of the CFA are as follows:

- (i) Work with DOE for preparation of reports and other documents required by the Energy Policy Act legislation.
- (ii) Develop a detailed integrated R&D strategy for complying with the objectives of the legislation, building on existing strengths at each member institution, especially under phase II of the proposed overall program.
- (iii) Work with DOE and congressional/senatorial staff for development of necessary appropriations language (FY 06 Supplemental –FY2010).

This objective of this project was to initiate preliminary efforts associated with SIU participation in the CFA. The effort undertaken was intended to facilitate completion of the short term objectives of the CFA and to position the State of Illinois and SIU for future participation in federally funded R&D as proscribed in the Energy Policy Act.

Task 1. Staff/Support staff /Graduate Students

The objective of this task was to hire personnel that will carry out the objectives of this project such as initial experimentation and I-lab set up and to anchor preliminary effort related to participation in CFA activities (under the supervision of SIU Faculty).

Task 2. Facilities design and specification

The objective of this task was to design a facility that will house a modular, flexible FT laboratory within the SIU College of Engineering and Coal Development Park for small scale FT studies and for education and training purposes.

Task 3. Travel and communications

The objective of this task was to engage in meetings and discussions with CFA partners, DOE, and other facilities such as GTI to coordinate the CFA activities and build future collaborations. In addition, the objective of this task was also to attend meetings and conferences in this research area.

Task 4. Symposium

The objective of this task was to organize a symposium that will act as a forum to bring together interested parties to discuss and review existing FT technology, environmental aspects of FT liquid production and utilization, and to discuss policy and technical barriers to commercial deployment of existing FT technology.

INTRODUCTION AND BACKGROUND

The recent spikes in oil prices sent the world's economies, especially western economies heavily dependent on oil, into a scramble to reduce their dependence on imported oil from the Persian Gulf region. Today, due to the size of its economy, the United States is still the largest importer and user of foreign oil, mostly from the Middle East. The United States is now in serious competition with rapidly growing economies for the world's available oil. There is a palpable sense and developing consensus that we are nearing the end of cheap oil, if not the end of oil entirely. As a result, production of liquid transportation fuels from domestic resources is becoming increasingly attractive on both commercial and energy-security grounds. Steeply rising petroleum prices make production of synfuels more financially attractive than has been the case in the recent past, especially if technical breakthroughs further improve overall process economics. Furthermore, a significant fraction of U.S. petroleum supplies are imported from areas with geopolitical stability issues. This makes U.S. military and civilian fuel supplies vulnerable to sudden supply disruptions, with likely concomitant disruption of the U.S. economy. An irony is that the United States already possesses one of the greatest supplies of energy in the world.

“The largest single increment of energy in the world is America's recoverable reserves of coal, secure within the borders of our country...The United States possesses 275 billion tons of recoverable coal reserves, or about one-fourth of the world's total. U.S. coal reserves are equivalent to four times the oil of Saudi Arabia, 1.3 times the oil of OPEC and equal to all the world's proved oil reserves.” (**Partners for Affordable Energy**, (http://www.affordableenergy.org/key_points/dependence.asp))

One potentially attractive route for production of liquid transportation fuels from domestically available resources is Fischer-Tropsch (FT) conversion of coal-derived syngas. The Illinois basin is a strong potential candidate for large scale development of FT liquid fuel production due to the abundance (and characteristics) of Illinois coal, the availability of abundant water resources, and the availability of relevant infrastructure and technical expertise.

The federal government has recognized the imminent threat of escalating prices and diminishing availability that could disrupt the US economy and has included its response in the Energy Policy Act of 2005. Specifically, Section 417 of the Federal Energy Policy Act of 2005 (Energy Policy Act), authorizes an initiative to promote the use of Illinois basin coals for production of liquid transportation fuels by Fischer-Tropsch (FT) type processes. The act specifies that this initiative is to be carried out jointly between the Purdue University Energy Center, the Southern Illinois University Coal Research Center, and the University of Kentucky Center for Applied Energy Research. The act authorizes (but does not appropriate) federal funding for this purpose.

An alliance (the Illinois Basin Coal Fuel Alliance – CFA) has been established between the three institutions named in the legislation and a Memorandum of Understanding has been co-signed by all participants.

A preliminary three-phase work plan for achieving the objectives of the Energy Policy Act has been developed (and continues to be refined). This plan will be carried out jointly by all CFA participants primarily using federal monies once these are appropriated.

Phase I – Detailed analysis of technological bottlenecks and commercialization barriers in existing and high-potential near-term technologies, including development of process and economic models. Prioritization of research goals and the setting up of the overall research and development plan with cost estimates of various options. Additionally, the following tasks will be also performed:

- Identification of other institutional/government (DOE)/industrial partners.
- Organizing symposium/workshop series for full identification and characterization of the present knowledge.

Phase II – Implement focused R&D program at designated institutions (in collaboration with other public/private/academic partners as appropriate) to address technological barriers identified in Phase I.

- Syngas preparation for F/T process (optimization of H₂/CO ratio and removal of impurities).
- FT process/reaction chemistry/reaction engineering issues.
- Catalyst development and optimization.
- Product application.
- Design studies.
- Breakthrough opportunities.

Phase III

- Development/demonstration at test center magnitude size, preferably in conjunction with one or more commercial partners.

In the short term, the objectives of the CFA are as follows:

- I. Work with DOE for preparation of reports and other documents required by the Energy Policy Act legislation.
- II. Develop a detailed integrated R&D strategy for complying with the objectives of the legislation, building on existing strengths at each member institution, especially under phase II of the proposed overall program.
- III. Work with DOE and congressional/senatorial staff for development of necessary appropriations language (FY 06 Supplemental –FY2010).

The project aimed at conducting activities to enhance the State of Illinois' leverage to acquire federal funds in this area as well as to participate in CFA activities. These were achieved through hiring of personnel, design of a flexible I-Lab, and acquisition of necessary laboratory and process equipment.

PROCEDURES

Task 1. Staff/Support staff /Graduate Students

The standard hiring procedures of position approval, advertisement, and interview, selection, and hiring approval as enunciated by the regulations of SIU, were followed for hiring full time researchers. Two graduate students with chemical engineering degrees were also hired to assist in the development of the design of the modular FT laboratory space and conduct preliminary experiments. In addition, some temporary help were hired to organize and renovate the current capabilities to conduct FT process work.

Task 2. Facilities design and specification

The PIs in collaboration with Coal Research Center at SIU and other expert faculty in the College of Engineering have conducted discussions on the design of the facility. The purpose of the envisioned laboratory space is for small scale FT studies and for education and training purposes.

Task 3. Travel and communications

Several meetings were organized by the PIs. The travel arrangements were made for the PIs to attend CFA meetings, conferences, and one-on-one meetings with experts and GTI.

Task 4. Symposium

Several trips were made to attend planning committee meetings to arrange a symposium that will act as a forum to bring together interested parties to discuss and review existing FT technology, environmental aspects of FT liquid production and utilization, and to discuss policy and technical barriers to commercial deployment of existing FT technology.

RESULTS AND DISCUSSION

Task 1. Staff/Support staff /Graduate Students

One researcher, two graduate students with chemical engineering degrees, and some temporary help were hired to carry out the objectives of this project, such as initial experimentation and I-lab set up and to anchor preliminary effort related to participation in CFA activities (under the supervision of SIU Faculty). The personnel helped in the development of the I-lab design, conduct some preliminary experiments and redesign the current FT synthesis set up.

Task 2. Facilities design and specification

A facility was designed that will house a modular, flexible FT laboratory within the SIU College of Engineering and Coal Development Park for small scale FT studies and for education and training purposes. The design of the facility has been submitted to the State of Illinois along with a proposal to develop the facility based on the design. In addition, one reactor system has been purchased from Parr Instruments (Figure 1 - 3). The high pressure reactor system is fully equipped with pressure and mass flow controllers and liquid gas separators. This reactor will be housed in the I-lab facility. A gas chromatograph with 3 columns, flame ionization detector and thermal conductivity detector, and a ten port heated valve has been purchased to analyze the waxes and liquid hydrocarbons. This GC is currently online with the FT reactor system possessed by the PI. Another gas chromatograph with a FID and a TCD has been upgraded to contain a heated 6 port valve and house two columns to analyze CO, H₂, CO₂, and gaseous hydrocarbons and light liquid hydrocarbons up to octane.

Task 3. Travel and communications

The PIs have engaged in fruitful discussions with CFA partners in Lexington on several occasions within the duration of this project and are continuing the activities to obtain federal funds. In addition, representatives of the CFA partners (including the PIs) have

met with US DOE representatives to discuss these issues. In addition to these meetings, the PIs have attended the meeting of the local chapter of the American Institute of Chemical Engineers that focused on the present state of the art of FT synthesis and had a one-on-one meeting with Dr. Burton Davis to discuss future possibilities. The PIs also attended conferences held by the Indiana Center for Coal Technology Research at West Lafayette and in Valparaiso that discussed the current state of FT process, future research needs, the role of the government in promoting FT activity, CFA activity, and the I-lab concept. Within the state, the PIs are engaged in intense deliberation with GTI with respect to each others capacities, identifying synergies for future collaborations, and the ability of the two state entities to leverage federal funds for FT capacity development in the state.

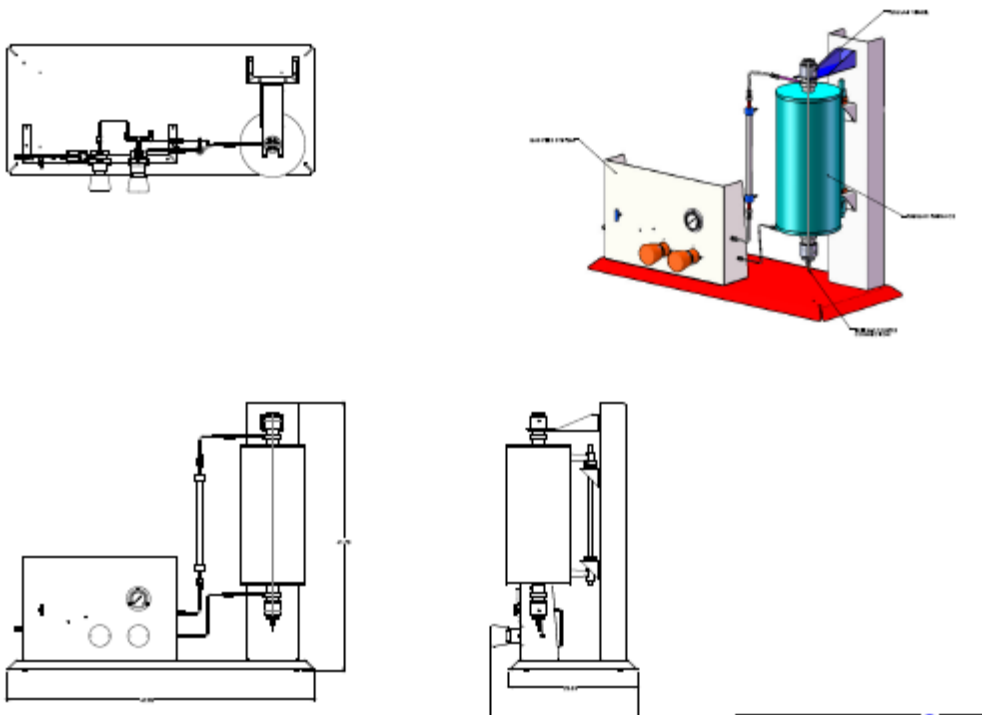


Figure 1 New high pressure tubular reactor layout



Figure 2 The High pressure reactor system

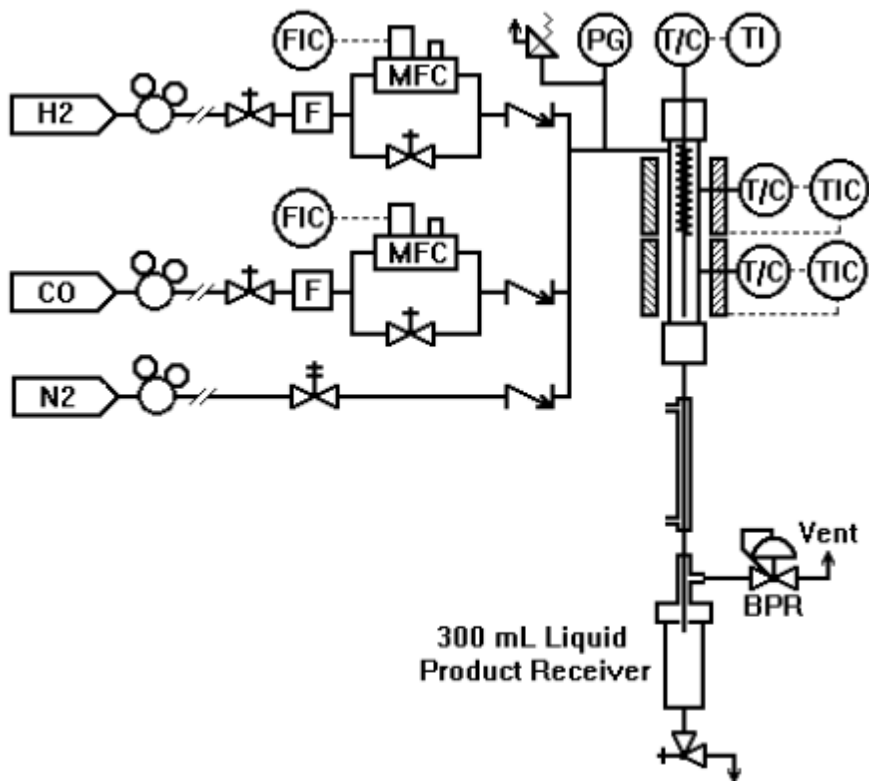


Figure 3 - Schematic of the Reactor setup

Task 4. Symposium

In March 2007, the American Chemical Society held its national meeting in Chicago Illinois. One of the technical themes for this meeting was Energy Sustainability and Security. Dr. Ken B. Anderson (Department of Geology, SIUC) was the national program coordinator for this programmatic area at this meeting. Keynote speakers, including several Nobel Laureates for individual symposia and several high profile speakers participated in the policy-focused event, including Secretary-of-State Rice and Illinois Senator Obama. Dr. Ari Geertsema (formerly UK CAER) presented a keynote address in the Presidential technical session that included a discussion of the use of coal as a source of synthetic transportation fuels by FT processes.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were made from the analysis of the data:

- 1) The hiring of personnel has begun.
- 2) The travel and meetings have resulted in the identification of the focus of the CFA and the path to achieve them.
- 3) Several new partnerships have been identified that would help the State of Illinois to take a leading role in coal to liquids fuels development.
- 4) New equipment has been purchased.
- 5) The I-lab design has been completed and new funding was made available for the construction, renovation, and set up of the I-lab.
- 6) A symposium on FT technology was organized as a part of the American Chemical Society's annual meeting.

It is recommended to continue on the present path towards development and deployment of coal to liquid fuels technology.

DISCLAIMER STATEMENT

This report was prepared by Dr T. Wiltowski, SIUC, with support, in part by grants made possible by the Illinois Department of Commerce and Economic Opportunity through the Office of Coal Development and the Illinois Clean Coal Institute. Neither T. Wiltowski, SIUC, nor any of its subcontractors nor Illinois Department of Commerce and Economic Opportunity through the Office of Coal Development and the Illinois Clean Coal Institute, nor any person acting on behalf of either:

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