Adding Value to Wyoming's Coal Resource—

value

the next generation

Prep

Prepared by the Wyoming Natural Gas Pipeline Authority, the Wyoming Infrastructure Authority, and the University of Wyoming Office of Research, in conjunction with the Idaho National Laboratory Program for Alternative Fuels and Energy Systems

September 1, 2005

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Nomenclature

BPC	Buffalo Power Company
BPD	barrels per day
BTU	British thermal unit (thermal energy measurement)
CFB	circulating fluidized bed
CTL	coal to liquid
CTSF&E	coal to synfuels and electricity
DoD	Department of Defense
DOE	Department of Energy
EOR	enhanced oil recovery (usually with high pressure CO_2)
F-T	Fischer Tropsch (catalytic method of converting syngas to liquid hydrocarbons)
FutureGen	Federally sponsored program to convert coal to hydrogen and carbon dioxide
Gasification	(partial oxidation of coal to produces synthetic, combustible gas)
IGCC	integrated gasification combined cycle (gas combustion turbine and steam turbine)
INL	Idaho National Laboratory
IRR	investment rate-of-return
NOx	oxides of nitrogen (pollutants)
PC	pulverized coal
PM	particulate matter (pollutants)
SCPC	supercritical pulverized coal
SOx	oxides of sulfur (pollutants)
Syngas	synthetic gas produced from coal gasification containing CO, CH_4, H_2, and CO_2
USCPC	ultra-supercritical pulverized coal
Tailgas	gas effluent with unconverted syngas or unreacted compounds still present

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Executive Summary

This paper has been prepared at the request of the Joint Mineral, Business and Economic Development Committee of the Wyoming Legislature to focus on technology and public policy paths that will help Wyoming realize more value from its coal resources.[1] Adding value to Wyoming's coal resources is critical on two fronts – to sustain our economic position as the leading energy-producing state in the U.S., and to ensure that energy technology advances are a key component of Wyoming's energy strategy. If technological advances find application in Wyoming, value added will also be manifest in improved energy production efficiencies and mitigation of environmental impacts.

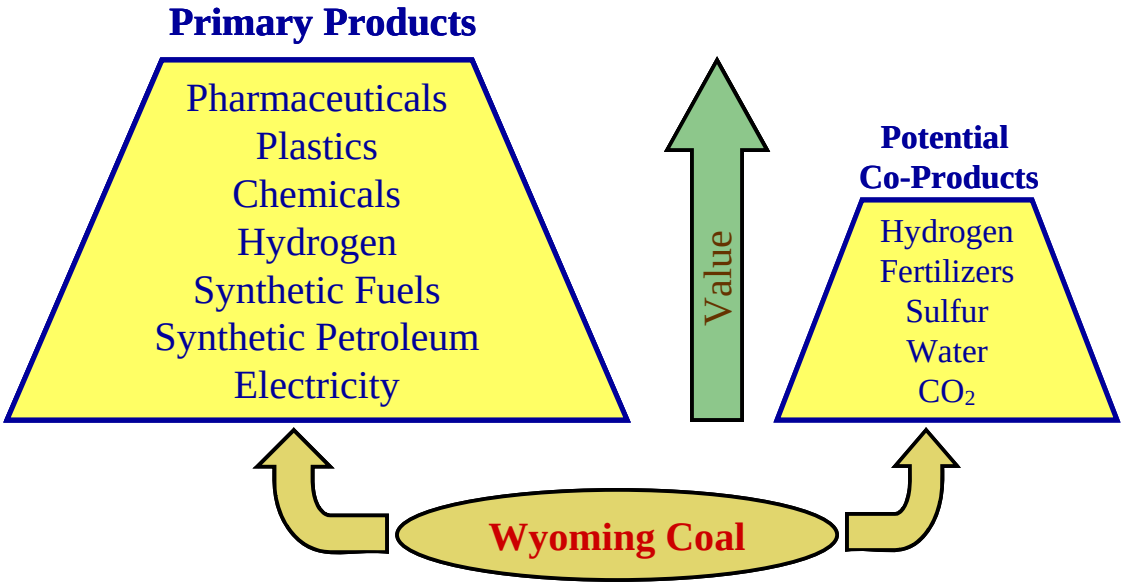
Included herein is an inventory of emerging coal technologies and pending advanced technology projects that are being pursued in Wyoming by the private and public sectors. This paper also provides a brief summary of incentives being offered by two other states and by the Federal government to promote the development and commercial viability of these new technologies. Finally, specific public policy recommendations are offered that could hasten clean coal technology deployment in Wyoming.

For the purpose of this paper, "value added coal" refers to the development and utilization of the coal energy resource, within Wyoming, in a manner not yet in widespread commercial application across the U.S., through deployment of advanced technologies that also further reduce emissions related to energy production, compared against conventional practices. Thirty-five percent of the coal consumed in the U.S. annually is produced in Wyoming, the vast majority of which is exported for power production out-of-State. "Value added" as used herein therefore also means that the process utilized to add to the fair market value of the coal resource, above its market value for export by rail, occurs within Wyoming, thereby enhancing the economic value to the State and its overall value to those who live and work here.

Wyoming's coal market potential can be viewed in terms of a value chain. Currently, the commodity, coal, is produced and primarily directly sold for use in electricity generation. But in the future there are a number of products and co-products that will be profitably produced from Wyoming coal. If petroleum prices continue their recent upward trend, these value-added markets will become increasingly commercially viable. The figure below shows the value chain with coal as the base commodity, and its products above. As the value of coal-derived commodities increases, the likelihood of moving even further up the primary products value chain increases. Additionally, the co-products of water and hydrogen could have potential economic value as the nation moves toward a hydrogen economy.

[1] Just how great is the potential for Wyoming's coal resource into the future? The energy producing potential of coal in the Powder River Basin alone is greater than the amount of energy that will ultimately be produced in Saudi Arabia.

Value Chain For Coal Conversion Processes



Enactment of the Energy Policy Act of 2005 signals the Federal Government's intent to stimulate and support clean coal technology, synthetic fuels production, renewable energy development, increased refinery capacity, and nuclear power advancement. From an economic development perspective, Wyoming can benefit by participating in these programs.

Wyoming should develop a Western Integrated Coal Gasification Demonstration Project and design it to qualify for, and receive, Federal assistance from existing and new program initiatives. Aggressive pursuit of such a project will help align key industrial partners, coal mine owners and operators, and electrical utilities to establish both independent and joint electric power generation and synthetic fuels projects in the State. A demonstration project could play a critical catalyst role in meeting the increasing power needs and fuel transportation demands in the Western U.S., and may be dependent upon, and intertwined with, the expansion of pipeline infrastructure and the electric transmission grid.[2]

Several promising, value added, advanced coal technology projects are already planned for Wyoming. Section IV provides a summary of those where information for this report has been offered by the respective project sponsors. The Appendix to this report is a summary of the Department of Defense Clean Fuels Initiative, which is worthy of Wyoming's pursuit to become home for one of the planned Federal clean fuels production facilities. The concept of a Western Integrated Coal Gasification Demonstration Project is to leverage basic research and Federal funding resources and to help commercialize private-sector development of value-added coal utilization in Wyoming.

Electrical utilities in the Midwest and Eastern U.S. are currently planning several new integrated coal gasification combined cycle (IGCC) power generation plants. IGCC technology has been proven to be efficient for high BTU, low moisture bituminous coals. It can reduce pollutant emissions by a factor of four compared to standard pulverized-coal plants. Furthermore, it provides a platform for the U. S. Department of Energy's plans for a combined electric production, hydrogen production, and CO_2

[2] The Wyoming Natural Gas Pipeline Authority and Wyoming Infrastructure Authority have been established by the Wyoming Legislature to address energy transportation issues and are pursuing these economic expansion opportunities.

separation and sequestration demonstration (i.e. FutureGen) project. Wyoming's strategy for sustaining the growth of its energy-based economy must factor in the ever-changing trends in this industry, driven by technology advances, an international market for energy commodities, and Federal and State policies, whether they relate to incentives or environmental regulations.

Gasification is also emerging as the preferred process for converting coal into synthetic fuels and chemicals. The potential for pollutant emission credits and trading create further incentives for IGCC technology entry in the market by indirectly reducing plant operating costs. Global climate control initiatives and tighter mercury emissions regulations are also possible, which could foster further incentives for the electric power industry to consider advanced coal conversion technologies.

Market penetration studies suggest that many existing pulverized coal (PC) plants will be replaced over the next 20-30 years, with IGCC plants becoming 20-25 percent of the future electrical power generating capacity. Should this occur, Wyoming coal markets in the East could decrease since IGCC can effectively use high sulfur eastern coal. Therefore, it is important that Wyoming develop new market opportunities and new products that align it with pending electrical transmission line projects to help ensure a sustainable market for its coal. Such projects would increase the number of jobs within the State, and shift the job force to higher paying jobs. They would also help sustain Wyoming's energy-centered economic base.

Wyoming's strategic efforts to promote advanced energy technology deployment need to involve public-private partnerships, public policy initiatives by the executive and legislative branches, and be supported by a strong research and development team to help determine and select the most economically efficient and technically viable technologies and energy systems. Partnerships with other states and research organizations also are essential for developing the best projects. Cooperative agreements among research entities like the University of Wyoming and the Idaho National Laboratory (INL) are encouraged in the Energy Policy Act of 2005.

Wyoming's unique resource set includes vast coal reserves and geologic formations which have potential for carbon sequestration. Wyoming also has a well developed mineral transportation system, and the means for developing additional pipeline and electric transmission infrastructure, as needed, to support value-added mineral conversion to marketable products, such as synfuels and electricity. Thus, Wyoming has the potential to evolve beyond its current minerals extraction-based economy to include production of value-added energy products such as electricity, synthetic natural gas and synthetic fuels (synfuels), chemicals and plastics, and even pharmaceuticals from coal. The state also is strategically located in the U.S. interior with access to West Coast and Midwest markets and defense bases that are seeking secure fuel derived from the country's most stable fossil resources (coal, oil shale, and tar sands).

Despite many strategic advantages, in particular the abundance of Wyoming's coal resources, and the political and public support for an energy-centered economy, the majority of early attention toward advanced coal technologies by Congress and utilities has been focused on Eastern markets, and high BTU, low moisture bituminous coals, along with technology applications suitable for relatively low elevations.

Illinois recently enacted legislation aimed at revitalizing the Southern Illinois coal industry. SB 1814 adds FutureGen to the types of developments eligible for tax and financing incentives through the Illinois Coal Revival Program, which is administered by the Illinois Department of Commerce and Economic Opportunity (DCEO). FutureGen is a proposed Federal program that will include a research center and coal-fueled production of electric power and hydrogen fuel cells. The DCEO is now authorized to provide FutureGen, along with other innovative coal gasification projects, with a wide range of incentives, from tax exemptions and credits to low-cost financing through DCEO's Coal Revival Program. The Illinois Finance Authority also has up to $300 million in bonding capacity to support clean coal development projects.

Illinois serves as a vivid example of the growing competition Wyoming faces for the development of advanced coal technology projects. Additional examples of Federal and State incentives for advanced coal technology development are covered briefly in Section III of this paper.

It is recommended that Wyoming pursue projects identified in the Energy Act of 2005 that align with its strategic and tactical interests. In particular, projects associated with higher value added use of Wyoming coal, such as IGCC demonstration projects, synthetic fuels plants, and other related developmental opportunities should be pursued. **A public-private coalition should be organized, led by the Governor and members of the legislative Minerals Committee, joined by representatives of the University of Wyoming and industry, to immediately solicit federal consideration of Wyoming as the site for deploying a commercial-scale Western Integrated Coal Gasification Demonstration Project, with both IGCC demonstration and DoD clean fuel elements.**

Wyoming's current enviable position as the leading energy producing state in the U.S. must not be taken for granted. New power generation facilities and coal conversion plants will be in service for decades. Competition for these projects already is becoming fierce. Wyoming's current revenue surplus, derived from energy, should be reinvested in part back into its energy economy to sustain its economic contribution over the next several generations and beyond. **Specifically, the Wyoming legislature should consider legislation in the next session as an incentive and encouragement to new advanced technology and value-added projects. Such legislation should not favor a specific developer or advanced technology but offer a suite of enabling tools.**

The following is a list of public policy incentives that have been identified through our research for your consideration. They are not meant to be additive, but rather individual options. Neither are they all preferred options to those organizations that have collaborated to prepare this report:

- **Eliminate sales and use tax associated with the purchase of equipment used to construct new coal gasification or coal liquefaction facilities, as well as pipeline and electric transmission facilities which are identified as directly related to these facilities.**
- **Establish a severance tax credit for all (or a portion) of the coal used to create a value added coal product, for a period certain, or over the life of the project.**
- **Establish a matching grant program, modeled on the Illinois program, to provide a fractional cost share on select projects based upon economic criteria. Special emphasis should be given to partnering with Federal demonstration program initiatives as a match to Federal funding.**
- **Offer commodity price floor support, capped at an overall dollar limit, below which the State would offer price support in relation to unit commodity production costs and above which the State would share in the revenue stream.**
- **Authorize the Public Service Commission to grant incentive cost recovery mechanisms on the Wyoming-allocated share of advanced technology clean coal investments by regulated utilities, particularly those achieving reductions in emissions below levels associated with traditional pulverized coal technology.**

Adding Value to Wyoming's Coal Resource – the Next Generation

I. Profile of Advanced Coal Technologies

Coal-fired electric generating plants supply more than 50 percent of the electricity in the United States and are projected to continue to do so through 2025 and beyond. The majority of these power plants currently utilize conventional pulverized coal technology with subcritical steam conditions of 2400 psi and 1000 degrees Fahrenheit and energy conversion efficiencies of less than 37 percent. (Energy conversion efficiency refers to the energy output as a percentage of energy input.)

The choice of future technology options for new coal-fired power plants will benefit from commercially available and emerging advanced clean coal technologies such as supercritical and ultra supercritical pulverized and circulating fluidized bed combustion technologies, integrated gasification combined cycle technologies, and polygeneration technologies for the co-production of electricity, fuels, and chemicals. These new and emerging advanced clean coal technologies typically demonstrate higher performance levels and lower emissions of criteria pollutants, while producing electricity at a cost that is nearing competitive levels with conventional coal-fired electricity production. In addition, most of these new and emerging technologies can be designed with CO_2 capture systems that are capable of removing 90 percent or more of the CO_2 emissions.[3]

Following is a summary of the suite of Advanced Clean Coal Technologies prepared by the Clean Coal Task Force of the Western Governors' Association Clean and Diversified Energy Initiative.

- Supercritical pulverized coal (SCPC) combustion where finely ground coal is injected into a boiler where it is combusted to produce supercritical steam that has higher pressure (3500 psi vs 2400 psi) and temperature (1050 vs 1000 degrees Fahrenheit) than most conventional PC power plants in service today. These higher steam conditions result in a greater efficiency of power production, and, with the addition of high performance emission controls, produces lower emissions of criteria pollutants (SO_2, NOx, particulate, and mercury) per unit of electricity output. SCPC technology is commercially available.

- Ultra supercritical pulverized coal (USCPC) combustion is the same as SCPC except that with the introduction of boiler parts made from advanced materials, steam conditions can be raised even higher (4500 psi and 1100 degrees Fahrenheit). With the development of advanced materials for production of critical boiler and turbine parts, it is expected that USCPC technology will be commercial demonstrated and available before 2015.

- Supercritical circulating fluidized bed (CFB) combustion differs from PC combustion because pea-sized coal and limestone particles are injected into the boiler, which is filled with spent bed material (primarily ash, free limestone, and calcium sulfate). Air is injected at the bottom of the boiler, which causes the coal and spent bed material to rise and mix rapidly, making it appear to be fluidized. Combustion gases and a portion of the spent bed material are carried out the top of the boiler and enter a cyclone where the combustion gases and the majority of the spent bed materials are separated. The combustion gases are subjected to further clean up and enough of the spent bed material is returned to the boiler to maintain the amount required

[3] CO_2 capture at conventional plants is both energy intensive, consuming between 14% and 28% of the units capacity, and expensive, increasing the cost of electricity between 47% and 87%. However, the U.S. Department of Energy with the participation of States, Universities and private researchers has undertaken a major research, development and demonstration effort with the goal of reducing the power consumption and cost to capture CO_2 from both combustion and gasification technologies which is expected to result in commercial designs ready for full scale demonstrations beginning in 2012 that increase the cost of electricity by no more than 10%.

for fluidization. Because of the complete and rapid mixing caused by fluidization, a much broader range of solid fuels can be used and the boiler temperature is lower (1500 degrees Fahrenheit vs up to 2400 Fahrenheit for PC boilers), which allows the limestone to capture and retain sulfur dioxide, and which also lowers the amount of NOx that is formed. By designing the CFB combustion boiler to achieve supercritical steam conditions, the efficiency of the technology can also be increased, resulting in lower criteria pollutants and CO_2 emissions per unit of electricity generated. Supercritical CFB combustion units have not been demonstrated on a commercial scale, but several subcritical CFB boilers are in operation today.

- Integrated gasification combined cycle (IGCC) technology combines a gas turbine cycle with a steam turbine cycle to produce electricity. Coal is converted to a fuel gas (syngas) consisting of hydrogen, carbon monoxide, CO_2, some methane, and low amounts of gas contaminants. Gasification is done through partial oxidation of the coal in a gasifier in the presence of either air or oxygen. The fuel gas must be treated to remove the contaminates (sulfur, nitrogen and mercury compounds) before it is combusted in the gas turbine. The waste heat in the exhaust of the gas turbine is used to produce steam to power the steam turbine. IGCC has been proven on a commercial scale for eastern coals. The high BTU content and low moisture of eastern coals are advantageous to IGCC plants. In addition, the high sulfur content of many eastern coals is no longer a disadvantage because, unlike conventional PC electricity generation plants, the sulfur can be easily removed from the syngas and can be economically converted into sulfur, sulfuric acid, or sulfur-bearing fertilizers that have commercial value. Hence, gasification represents a threat to Wyoming's low sulfur, sub-bituminous coal market because eastern coals will become more economically competitive. IGCC with CO_2 capture has not been demonstrated on a commercial basis, but the technology for shifting and capturing the CO_2 is being commercially used in refineries and industrial applications.

- IGCC with co-production of fuels and chemicals utilizes the same technology that is used in IGCC applications that produce electricity, except that a portion of the syngas, after clean up, is converted to high-value transportation fuels and chemical feedstocks. Co-production allows the gasifier to run at a very high capacity factor and to produce a greater portion of fuels and chemicals when electricity is not needed or when economics favor their production over electricity. Production of fuels and chemicals from syngas is commercial technology, but until recently the economics of co-production of electricity, fuels, and chemicals have not proven to commercially viable in the U.S.

II. Conversion of Coal to Liquids

Wyoming coal should be regarded as a valuable feedstock for synthetic fuels (synfuels) and high value chemicals given present world crude oil prices and expectations that oil prices are likely to remain high. Feasibility studies, such as Rentech's study funded by the Wyoming Business Council, suggest favorable investment economics for a combination Fischer Tropsch (F-T) synfuel project with co-production of electrical power. In a separate study, the break-even point for synfuels production from eastern coal was stated to be around $1.00/gallon of gasoline produced at the refinery gate.[4] A correlation between recent refinery production costs and the price of crude shows the crossover for economics favoring coal to fuels is conservatively around $30/barrel oil as shown in the table below. This figure corroborates the conclusions reached in the Rentech study which indicated significant profitability for a synfuels plant operating at a mine mouth in Wyoming when crude prices exceed $30/barrel. Other synfuel studies have determined that a coal-to-synfuels plant can be profitable competing with crude prices as low as $15/barrel.

[4] Robert H. Williams, Carbon Mitigation Initiative, Princeton Environmental Institute, Princeton University.

Year	Average Crude Oil Price	Average Price of Gasoline at Refinery Gate
1999	**$17.5**	**$0.66**
2003	**$28.5**	**$1.00**
2004	**~$40**	**$1.33**

The production of synfuels from coal is not new technology when considering the experience of Germany, South Africa, and the Northern Great Plains Synfuel demonstration project in North Dakota. However, it is important to consider market factors on a regional basis, matching the technology (i.e., gasifier) with feedstock (i.e., stream compositions), co-production incentives, and most importantly, systems integration and optimization. While the Rentech report is a reasonable initial feasibility study of potential technologies and process benefits, it should be noted that a more comprehensive and thorough front-end engineering and design (or FEED) feasibility study, based on detailed material and energy balance calculations for the integrated process, should be completed to address process capability, plant emissions, efficiencies, heat integration, and plant economics. This effort should be coupled with pilot-scale testing and demonstration. These activities are essential to deployment of a project that will be technically optimal, and economically competitive and sustainable. It also is imperative that the project forecast market entry timing and economic impacts of similar plants being constructed in the West (including oil shale projects), in the Midwest and interior states, as well as Canadian tar sand projects. In addition, the candidate project also should consider process upgrade flexibility in response to environmental factors such as carbon management requirements and incentives. Finally, a detailed water balance is necessary to develop a project that fully uses the high moisture content available in Wyoming coals. Cursory calculations indicate that surplus water can be produced by the synfuels plant. This water could be a valuable by-product for co-located activities.

Hydrogen demand as a commodity for ammonia and fertilizer production, and for crude desulphurization and cracking, is driven by predicable market factors. Therefore, it may be prudent to design the synfuels plant to meet current market demands for power and synfuels, but with the capability to transition a portion of the plant toward hydrogen production as that market develops in the future.[5]

Economically beneficial uses of CO_2 co-production need to be considered for regional uses, including coal-bed methane production and enhanced-oil recovery (EOR). Future carbon sequestration regulations in the form of tax credits or penalties for emitters of CO_2 and payments for those that sequester CO_2 are possible; therefore, it is prudent to consider power and synfuels projects that can be upgraded and transitioned to optimally separate and sequester CO_2.

One virtue of gasification of western sub-bituminous coal is that the excess moisture in the coal may be viewed as a resource for a combined IGCC and PC or CFB power generation project or for renewable energy production. As much as 50 percent of the moisture in the coal can be extracted by properly matching gasifier selection and coal preparation operations with this objective. Consider, for example, that a dry-feed gasifier would require extraction of 50-90 percent of the moisture from Wyoming sub-bituminous coal. This moisture may be sufficient to provide cooling for a co-located standard PC or CFB

[5] In spite of much high level talk about the hydrogen economy, climate change, carbon sequestration, and growing interest in nuclear power, it is extremely difficult to anticipate societal attitudes and government action that will necessitate coal gasification to produce hydrogen. It is unlikely that coal gasification will be used in the foreseeable future to produce pure hydrogen on a wide scale for power generation, as proposed in the Federal FutureGen project. Nor is it likely that hydrogen generation for light-duty vehicles will be needed for several decades due to factors unnecessary to mention herein. A key consideration for Wyoming is the abundance and market value of natural gas since hydrogen production by steam methane reforming will favor hydrogen generation from natural gas over coal unless gas prices reach $10-15 MMBtu.

power generation unit. Alternatively, with little to only mild treatment, the warm water by-product can be impounded and immediately used to raise crops that are easily convertible to bio-diesel, or that can be converted to any of the value products using a biomass gasifier. Feasibility studies for conversion of biomass to bio-diesel, syngas, chemicals, and hydrogen have either recently been completed by the National Renewable Energy Laboratory or are currently in progress. Co-production and conversion of biomass to energy can potentially constitute 3-5 percent of the product line and would be considered "greenhouse gas" reducing or "carbon-neutral." It is recommended that systems integration and trade-off studies be performed to make judicious use of the excess water available in the coal, and any water that could be produced from coordinated activities that produce water, such as coal-bed methane production.

The 2005 Energy Policy Act calls for a Western Integrated Coal Gasification Demonstration project. The issues outlined above could be fully examined by a public-private coalition and supported by Federal funds. The Department of Energy will be the lead agency in determining the location of a development project in the West. **The Wyoming coalition should get organized quickly and develop a specific proposal to DOE for deploying a Western Integrated Coal Gasification Demonstration Project in Wyoming.**

III. Federal and State Incentives Promoting Advanced Coal Technologies

The Energy Policy Act of 2005 provides substantial funding and resources for alternative energy and value-added approaches addressing our nation's energy supply, and to a lesser extent, managing our consumption of energy. Projects chosen are intended to advance efficiency, environmental performance, and cost competitiveness.

With regards to coal gasification, the "Clean Coal Initiative" authorizes $200 million per year for FY'06 – FY'14. At least 70 percent of the funds must be spent on gasification projects. The Act breaks down allocation by BTU content, with 41 percent earmarked for western coals (7 kBTU/lbm to 9 kBTU/lbm). Another criterion is that the production needs to be implemented at elevation of at least 4,000 feet. Both criteria make western coal producing regions a viable area for a Coal Gasification Demonstration Project (especially Wyoming, Colorado, and New Mexico). Senator Thomas (R-Wyoming) was responsible for this specific language in the bill.

The Act also expressly authorizes a Fischer-Tropsch project for transportation fuels production from Illinois Basin coals. The DOE will have to authorize and fund a second project for development in the West. Added justifications are needed to support a Western Project focused on synfuels, although the justifications are obvious given the Class I Air Sheds and large urban areas. Class I Air Sheds occur on the west side of the State, in the Powder River Basin, and in Western South Dakota associated with several National Monuments and Parks. Hence, permitting for pulverized coal plants are increasingly difficult because of Clean Air issues in these areas.

Other potential opportunities for a Western Energy project include Indian reservation grants and preferential sales contracts for energy projects located on Reservations. Also, under the motive of energy independence (Sec. 252), funds are authorized for energy projects to facilitate energy independence. Up to $500,000 per year is authorized for planning and analysis, with $4,000,000 per year for three years for implementation.

Illinois and Minnesota are particularly exemplary in their use of incentives to promote advanced coal technologies. Their efforts are summarized here to illustrate state incentives and are not intended to cover the full spectrum of state incentives in the U.S. It should be noted that these and other states do not share in Wyoming's current prominence related to coal production. They do serve to effectively demonstrate the intense competition among states and regions in their promotion of "value added" advanced coal technology projects.

Illinois is proactively supporting coal revival using advance clean coal technology that is environmentally and performance-favorable to Illinois high-sulfur coal. In 1997, Illinois began a Coal Competitiveness Program to leverage private investment in coal production, transportation, and utilization. The Program provides up to 20 percent cost share for select projects based on economic criteria. The Program is now backed with a $500 million bond authorization for financial assistance (in the form of grants) to new electricity generating projects. In 2005, $50 million was appropriated for new projects. To qualify, facilities must generate 400 megawatts of electricity and create at least 150 Illinois mining jobs. Grant amounts are determined by potential tax revenues derived from new Illinois coal purchases for the plant. Illinois has further implemented an education and marketing strategy to heighten public understanding about coal's economic importance and to create a positive public image with respect to expanding its coal markets.

The State of Minnesota also is offering grants for clean energy studies. Minnesota derives part of its funding from a spent nuclear fuel storage variance account and re-invests a portion of the settlement revenue in renewable energy alternatives. Gasification technology has received several study awards. As a consequence, entities in Minnesota are beginning to view IGCC as a favorable alternative to electric power generation using PC technology.

Both State and National policy can encourage rapid market penetration of advanced coal utilization technology. State financial policies, including tax considerations, matching funds or bonding, rate incentives, and regulatory and industrial citing considerations are being used to attract deployment of coal gasification and synfuel plants. Incentives, if used, should close the gap in the life-cycle cost of electricity between IGCC and competing alternatives, without increasing project cost or risks to qualify for these incentives. Prompt action is encouraged in Wyoming if it is to capture a strong share of the market in the West, prior to the entry of potential competition in adjacent states.

IV. Advanced Coal Technology Projects Planned for Wyoming

The following is a summary of promising advanced coal technology projects currently planned for deployment in Wyoming.

Clear Energy Solutions Project

Clear Energy Solutions, a Wyoming LLC formed in December 2004, proposes to construct a facility that will co-generate electricity and produce a substitute for #2 refinery diesel fuel by combining proven coal gasification with synthetic fuel technology successfully deployed in South Africa for more than thirty years. While the electrical and fuel output of the first plant will be offered to support development and resolve air quality issues in Wyoming, the Project is intended to serve as the foundation for an industry that would open two new markets for Powder River Basin coal. The first is to export coal by wire to Western load centers. Here, the key advantage is the ability of the project to capture and sequester the CO_2 emissions for coal to synthetic fuels and electricity (CTSF&E) facilities while reducing NOx, SOx and PM emissions to trace levels. The second is to add long-term jobs and a technology focus to the Wyoming economy as the center of a coal-to-synthetic fuels industry. These fuels will contain zero sulfur and are able to transform any mobile or stationary compression engine into an ultra low emission unit with tail-pipe emissions below that offered by the combustion of natural gas.

The project would be divided into commercial and research facilities. The first is intended to found an industry; the second to become a center of research and development providing a venue to scale to industrial size and to demonstrate new applications, such as air separation, catalyst, and emerging gasification technologies for sub-bituminous coal.

The Wyoming-centered commercial CTSF&E facility will be designed to co-generate 300 MW of net export electrical output and produce 25,000 barrels per day (BPD) of synthetic diesel. Carbon dioxide

emissions will be captured and offered for enhanced oil recovery and coal-bed methane release. The CO_2 could also be available for sequestration (without a coal and oil recovery component). The initial Project and all successor plants will consume approximately seven million tons of coal per year and provide 250 full-time jobs.

The Buffalo Power Company Project

Buffalo Power Company ("BPC") has arranged for purchase of coal methane gas from coal gasification to fuel its Glenrock, Wyoming plant. The process is an IGCC system using coal as the feedstock. A corporate party owns the proprietary technology for the process. The technology has been significantly improved and refined to permit the IGCC system to successfully compete in power bidding contexts. This technology development work also has significantly reduced the capital costs of the IGCC system. The gasification firm will own its plant and coal supply, and will form a joint venture with BPC to locate on the BPC Site and produce coal gasification methane for BPC.

The coal supply for BPC gasification is available, short and long term, in or near the Powder River Basin of Wyoming. It is unsurpassed as a competitively priced coal resource in the domestic market. It will be transported by rail adjacent to the BPC power plant site at Glenrock. As stated, the coal gasification plant also will be constructed at that site. The methane gas supplied by this entity from its gasification process will have a fixed price, with escalation, for the duration of the Power Purchase Agreement.

The environmental performance of the selected IGCC technology offers superior emissions control for low levels of NO and NO_2, carbon monoxide, unburned hydrocarbons, SOx, and PM. The emissions level of acid rain pollutants (including NO_2 and SO_2) are controlled by process design and integration with the turbine combustion system. Gas emissions from a combined-cycle power plant fueled with coal-derived syngas are closely similar to the emissions produced from gas well methane fuel. Additionally, the combined emissions from the gasification process, including coal mining and grinding, the air separation unit, and the syngas cleaning operations, are minimal.

Medicine Bow Coal to Liquid Project

Medicine Bow Fuel & Power, LLC, a wholly-owned subsidiary of DKRW Energy LLC, is developing a mine-mouth coal facility and a coal gasification and liquefaction plant at the Saddleback Hills Mine in Carbon County, Wyoming (the "Project").

The Project is expecting to produce 6 to 7 million tons of coal per year from longwall and continuous mining operations. The coal mine will extract high BTU, low sulfur bituminous coal from the Carbon Basin reserve area. This feedstock will be used for a planned on-site liquefaction facility and external coal sales to the market. Arch Coal, Inc., or one of its subsidiaries, will operate and maintain the coal mine for the Project.

The liquefaction facility is projected to produce up to 36,000 BPD of ultra clean diesel, naphtha, and other synthetic refined petroleum products that will be sold in the Rocky Mountain region. Power, CO_2, and other products will also be co-produced and sold. The coal gasification system utilized by the Project is a proven technology that enhances efficiency, reliability, and environmental performance. The Project's power will be produced by a combined-cycle gas turbine and steam turbine configuration, using the steam generated by the integrated gasification and coal liquefaction processes and the tail-gas (i.e., the unconverted syngas used for synfuels production).

The commercially available process has significant environmental advantages over power produced from coal and conventional gas turbines and over diesel fuel and naphtha produced from a conventional refinery. The process will strip virtually all of the CO_2 from the synthetic gas and channel it to an outlet

where it can be exported by third parties in liquid form to be used in tertiary enhanced oil recovery operations. Hence, the combination of new technology, and utilization of the CO_2, will result in electric power and synfuels with very low carbon and SOx emissions.

Once the gasification and liquefaction process technologies are selected, the Project will apply for the appropriate State and Federal permits to construct and operate the coal-to-liquids gasification/ liquefaction/power facility (or "CTL Plant"). The CTL Plant is anticipated to begin operation in 2010.

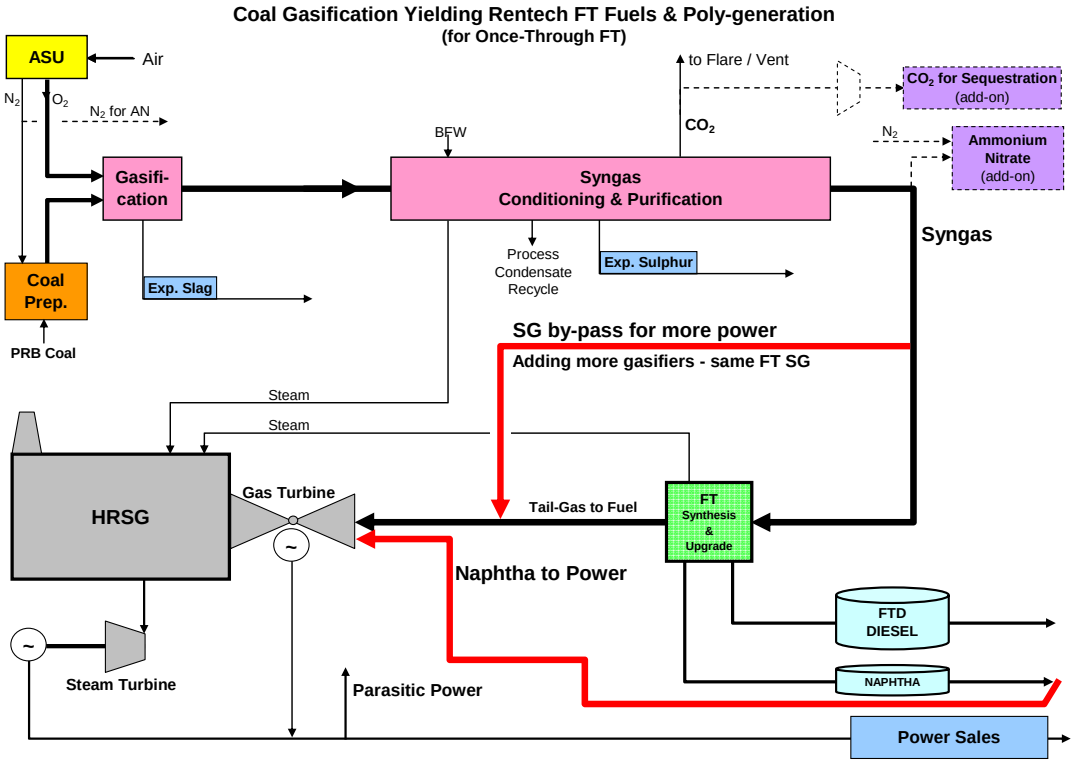
This project will be a major infrastructure facility that will employ 300-500 workers for the mine and the CTL Plant. Construction personnel will be required to build roads, buildings, pipeline, and power infrastructure to successfully implement the Project. It is estimated that the total Project cost will be in excess of $2 billion.

The Rentech PRB Co-Production Project, A Fischer-Tropsch/Power Facility

The following is a summary of a proposed Fisher-Tropsch project based on the results of the detailed economic viability study completed for the Wyoming Business Council.

Location: At a mine-mouth site in the Powder River Basin of Wyoming.

Project Design: The general design will include a dry gasification system, feeding clean syngas to a Rentech Fischer-Tropsch reactor. Product upgrading will use conventional refinery technologies to produce diesel, naphtha, jet fuel, and possibly ammonia-based and sulfur co-products. A general flow sheet for the project is shown to the right. Co-product CO_2 is also a potential add-on, depending on its economic value and carbon reduction incentives.

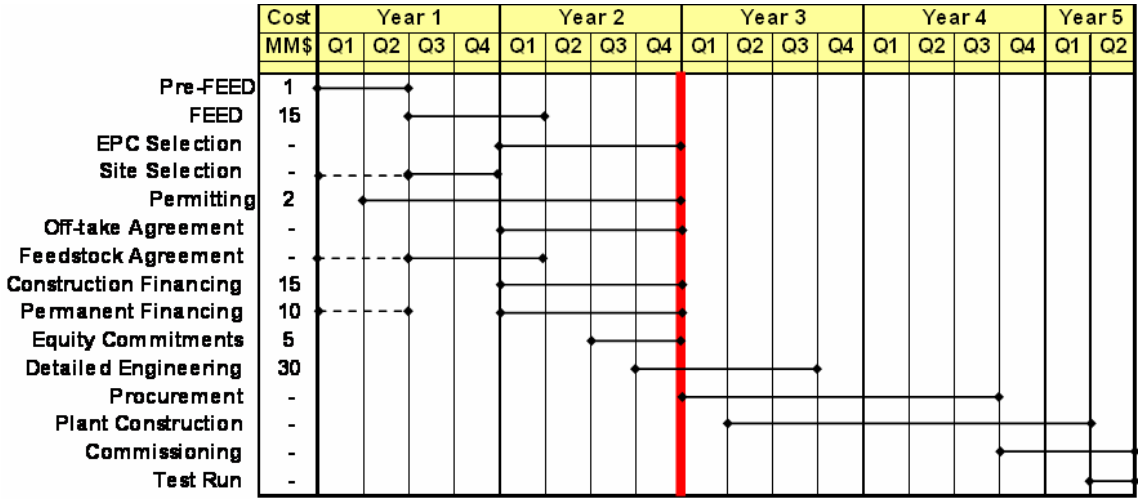


Coal Requirements: Approximately 2.5 million tons of sub-bituminous coal per year.

Economics: The project details for a net production of 10,200 BPD are summarized in the chart below. Based on a conservative $30 per barrel equivalent crude basis, the after-tax Investment Rate of Return (IRR) for this project on a 30/70 leveraged basis is ***20 percent***. Using current crude pricing in the $50 per barrel range, the IRR increases to 75 percent. Economic returns can be further enhanced with a change to a 12,000 BPD facility, maximizing the benefits of a single-train oxygen plant, and by adding additional gasification capacity for expanded power generation or poly-generation of ammonia chemicals, such as fertilizers and explosive compounds.

			Base Case
PLANT BASIS:	FT Flow Configuration:		Once-Through
	No. of GSP Gasifiers		6+1
	EPC-CAPEX	$ mill	740
	OPEX w/o Coal	$ mill/year	48
Main IMPORTS:	Coal Feed AR	STPD	7,650
	Oxygen Requirement	STPD	4,260
	Raw Water Import	GPM	240
Main EXPORTS:	FT Naphtha	BPD	1,640
	FT Diesel	BPD	8,560
	Total	BPD	10,200
	Net Power export	MW	104
	CO_2 Gas for Sale	STPD	1,600
	Sulfur for Sale	STPD	22
	Slag (vitrified) for Sale	STPD	310
STAFFING	Professionals		23
	Operators		112
	Other		47
	TOTAL Employees		182

Timing: The project will take approximately 4 ½ years from initiation of the project definition study until plant completion (as shown in the project schedule below). This schedule can be shortened given adequate and timely financing.



V. Summary & Recommendations

The movement to generate greater value from natural resources available in Wyoming suggests transitioning from extractive industries to higher value products. This movement up the value chain is essential to retain more of the true value of the natural resource within the geographic region. It is an evolutionary process that will enable the gradual development of an increasingly more sophisticated and stable industrial base. Using the regionally available resources (specifically Wyoming coal, but also oil shale), and applying the technologies described in this paper, will enable this movement and value realization.

Whether the objective is to generate electricity in a clean, efficient manner from coal, or to form the chemical precursors for fuel synthesis from hydrocarbon resources, gasification reactions comprise the key technology base. These reactions can be used to generate synthesis gas (i.e. carbon monoxide and hydrogen), and in turn that synthesis gas can be used in a number of different processes to generate electricity, fuels, or chemicals.

While the basic technical feasibility of IGCC and fuel synthesis is established, there remain several issues that need to be investigated to mitigate risk and insure the long term economic viability of these processes. The balance between power production and fuel synthesis from Wyoming coal is a question of critical importance. The system design should address this balance and allow for the introduction of new technology (e.g. sequestration of CO_2, hydrogen production) as it becomes technically feasible and economically justifiable. Opportunities to leverage the excess moisture in Wyoming coal also should be taken into consideration.

Wyoming's current enviable position as the leading energy producing state in the U.S. must not be taken for granted. New power generation facilities and coal conversion plants will be in service nearly a human lifetime. Competition for these projects already is fierce. Wyoming's current revenue surplus, derived from energy, should be reinvested back into its energy economy to sustain its economic contribution over the next several generations and beyond. **Specifically, the Wyoming legislature should consider legislation in the next session that provides incentives and encourages new advanced technology and value-added projects. Such legislation should not favor a specific developer or advanced technology, but should offer a suite of enabling tools.**

The following is a list of public policy incentives that have been identified through our research for your consideration. They are not meant to be additive, but rather individual options. Neither are they all preferred options to those organizations that have collaborated to prepare this report:

- **Eliminate sales and use tax associated with the purchase of equipment used to construct new coal gasification or coal liquefaction facilities, as well as pipeline and electric transmission facilities which are identified as directly related to these facilities.**
- **Establish a severance tax credit for all (or a portion) of the coal used to create a value added coal product, for a period certain, or over the life of the project.**
- **Establish a matching grant program, modeled on the Illinois program, to provide a fractional cost share on select projects based upon economic criteria. Special emphasis should be given to partnering with Federal demonstration program initiatives as a match to Federal funding.**
- **Offer commodity price floor support, capped at an overall dollar limit, below which the State would offer price support in relation to unit commodity production costs and above which the State would share in the revenue stream.**
- **Authorize the Public Service Commission to grant incentive cost recovery mechanisms on the Wyoming-allocated share of advanced technology clean coal investments by regulated utilities, particularly those achieving reductions in emissions below levels associated with traditional pulverized coal technology.**

It is also recommended that Wyoming pursue projects identified in the Energy Act of 2005 that align with its strategic and tactical interests. In particular, projects associated with higher value added use of Wyoming coal, such as IGCC demonstration projects, synthetic fuels plants, and other related developmental opportunities should be pursued. **A public-private coalition should be organized, led by the Governor and members of the legislative Minerals Committee, joined by representatives of the University of Wyoming (including the Western Research Institute) and industry, to immediately solicit federal consideration of Wyoming as the site for deploying a commercial-scale Western Integrated Coal Gasification Demonstration Project, with both IGCC demonstration and DoD clean fuel elements.**

We also recognize the University's report to the Joint Minerals, Business and Economic Development Committee discussing the establishment of a School of Energy Resources. This present White Paper and the University's report reinforce each other – specifically both act to position Wyoming as a leader in energy production, utilization and research. For example the Energy Act of 2005 authorizes the establishment of coal research centers in universities. UW will aggressively pursue such a center to assist in beneficiation of Wyoming's coal resources and embed the center within the proposed School of Energy Resources.

Appendix

The Clean Fuels Initiative

Office of the Secretary of Defense

VISION

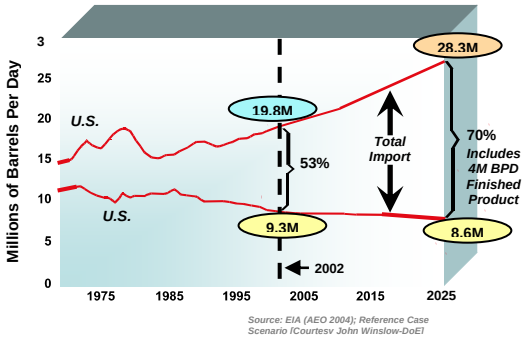
DOD intends to catalyze industry
to produce clean fuels
from secure domestic resources.
using environmentally sensitive processes
that creates jobs and wealth in the United States.

MISSION STATEMENT

An OSD Initiative
To evaluate, demonstrate, certify and implement
clean fuels produced from secure, diverse domestic resources
For use in all military tactical vehicles, aircraft and ships
To reduce DoD dependence on foreign oil,
To reduce DoD supply chain vulnerabilities,
And to reduce DoD pollutant emissions

Background:

- The increasing reliance on foreign supplies of energy, in particular crude oil and finished transportation fuels (such as military jet fuel), imported from some of the most unstable regions of the world is a growing concern for the Department of Defense (DoD). Currently, the US imports 56% of its crude oil and imports are projected to rise to 70% of the nation's requirements by 2025. In addition, the increasing use of a finite world supply of crude oil by rapidly developing nations, such as China, India, and other Asian nations, puts strain on the supply-demand balance and has contributed to the rapidly increasing cost of fuels for the U.S. military. Significant investment is going to be required to meet the world's energy requirements with the bulk of this investment currently slated for these unstable regions. Regional instability and competition for energy by developing nations could significantly influence the ability of the military to respond to worldwide situations.



US Imports On the Rise

- The U.S. military currently utilizes approximately 300,000 barrels per day of transportation fuels with 75% produced in domestic refineries. The vast majority of these refineries are clustered in mega refining centers along the coasts with a significant presence in the Gulf Coast region. Although the current system of supply, refining, and finished product distribution is very efficient and cost effective in meeting the military and commercial sector needs, inherent risks and vulnerabilities are present. One such case was demonstrated by the disruptions caused by

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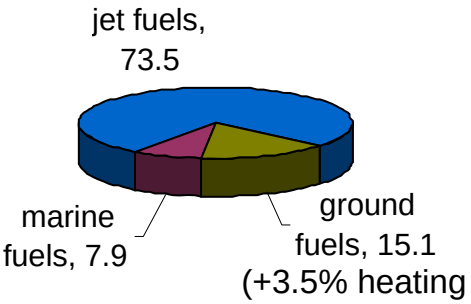
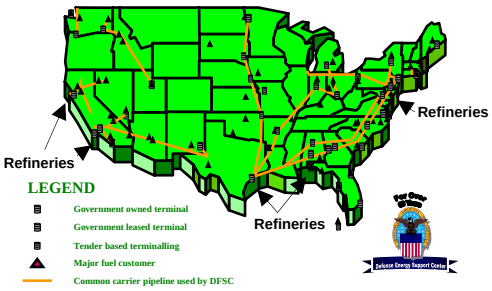
hurricane Ivan, which hit the Gulf Coast in 2004. In addition, the past two decades have shown a significant decrease in the number of US refineries with the mega refineries being expanded to make up for lost US capacity. As a result the overall fuel supply diversity has diminished and supply-demand imbalance situations can occur when unplanned shutdowns happen.

DoD Fuels -- 300,000 bbls/day



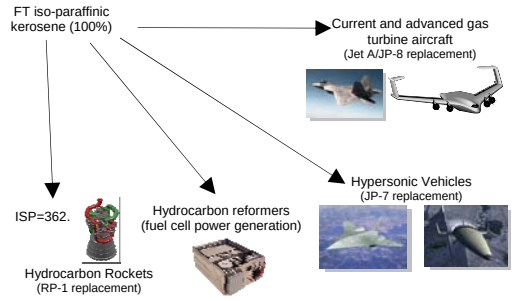
Source: DESC Contract Awards, FY03

Supply Chain Efficient
But Relies on Mega Refineries

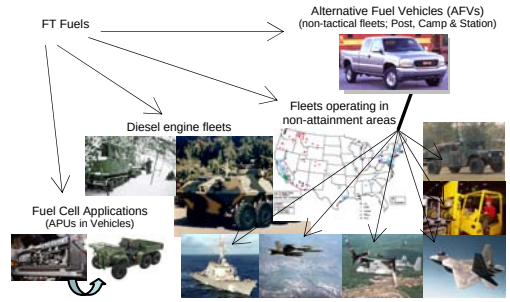


- The DoD has been working toward a more universal (single battlefield) fuel that can be utilized in current and legacy system as well as enable the next generations of hybrid propulsion, fuel cells, and hypersonic vehicles. Currently nine fuels are provided to our forces operating in the Middle East and Afghanistan, creating supply chain inefficiency. Environmental restrictions require the military to have a national security exemption for the use of JP-8 fuel in tactical vehicles in the United States and there are growing concerns that environmental laws in Europe may require the development of cleaner aviation fuels.

Battlefield Use Fuel of the Future (Aerospace)



Battlefield Use Fuel of the Future (Ground)



- The United States has approximately 800 million barrels of oil equivalent in its coal reserves and approximately 1 trillion barrels of unconventional oil in oil shale. Capture and sequestration of

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carbon dioxide from commercial production facilities transported to depleting oil fields would produce 32 billion barrels of addition oil from US reserves and sequester 13 billion tons of carbon dioxide. The United States contains vast resources of coal and oil shale (more than double those in the Middle East) that could be used to provide secure supplies of fuel to the military, local first providers (fire departments, police, ambulances, etc.), and the commercial sector. Secure, diverse fuel supplies would enhance national security and could provide a steady supply of fuel during a crisis situation.

Domestic Energy Resources

- **1.4 trillion barrels (shale)**
- **800 billion barrels of FT (coal)**
- **0.15 billion barrels (pet coke)**
- **22.7 billion barrels oil reserves**
- **32 billion barrels of oil (EOR)**
- **Renewables (TBD)**
- **Total 2.3+ trillion barrels**

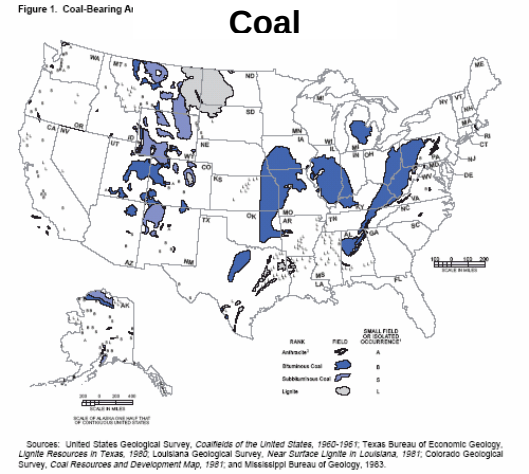
Middle East Reserves

Saudi Arabia:	261.8 Billion Barrels
Iraq:	112.5 Billion Barrels
UAE:	97.8 Billion Barrels
Kuwait:	96.5 Billion Barrels
Iran:	89.7 Billion Barrels
Qatar:	15.2 Billion Barrels
Oman:	5.5 Billion Barrels
Yemen:	4.0 Billion Barrels
Syria:	2.5 Billion Barrels

TOTAL 685.5 Billion Barrels

Oil Shale

Coal



Sources: United States Geological Survey, *Coalfields of the United States, 1960-1961*; Texas Bureau of Economic Geology, *Lignite Resources in Texas, 1980*; Louisiana Geological Survey, *Near Surface Lignite in Louisiana, 1981*; Colorado Geological Survey, *Coal Resources and Development Map, 1981*; and Mississippi Bureau of Geology, 1983.

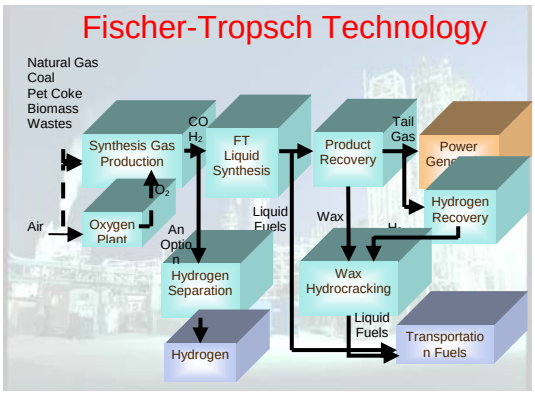
- *The US has more barrels of oil equivalent than the Middle East*

- Clean jet fuels can be produced via the Fischer Tropsch process from domestic coal, petroleum coke, natural gas and biomass. The U.S. Congress has supported one such program for military clean fuels by funding the research and production of Fischer-Tropsch (also known as Gas-to-Liquids) jet fuels. These clean jet fuels were produced as part of the Department of

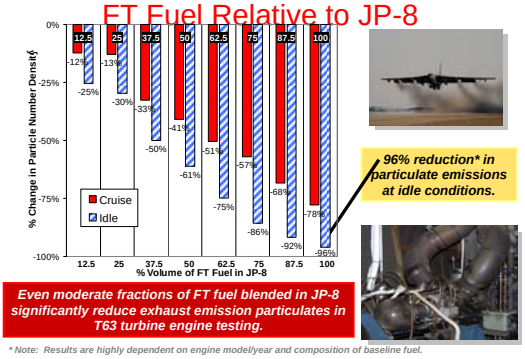
Appendix

Energy's Clean Fuels Program by Syntroleum Corporation (Tulsa, OK). These have been evaluated by the U.S. Air Force, Army, and Navy and show promise in meeting the requirements of the military while reducing overall tailpipe emissions. The initial results of this fuel program have mobilized the Department of Defense to form this new clean fuels initiative. Secure domestic shale oil can also be refined into clean transportations fuels and joint DOE/DoD initiatives in the 1970's and 1980's demonstrated the viability of producing jet fuels from this resource.

Fischer-Tropsch Technology



Reduced Particulate Emissions with FT Fuel Relative to JP-8

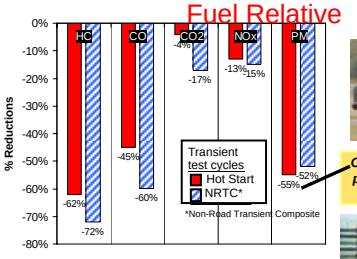


96% reduction in particulate emissions at idle conditions.*

Even moderate fractions of FT fuel blended in JP-8 significantly reduce exhaust emission particulates in T63 turbine engine testing.

* Note: Results are highly dependent on engine model/year and composition of baseline fuel.

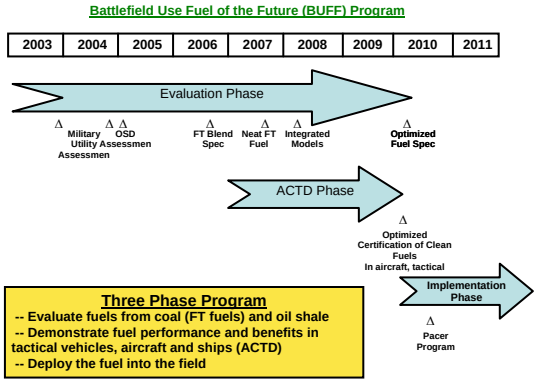
Reduced Exhaust Emissions with FT Fuel Relative



Over 50% reduction in particulate emissions in transient mode.

FT fuel burns more completely and emissions are signifcantly cleaner than EPA certified low-sulfur diesel fuel tested in 6.5L diesel engine.

- The DoD is working jointly with the Department of Energy (DOE) to develop a national initiative to develop, test, certify, and use jet fuels produced from these alternative energy resources. As many states hold large supplies of domestic resources, we are interested in coordinating at the state and federal level to help catalyze the development of these resources, which could provide for supply security and diversity, facilitate job and economic growth, and provide more environmentally friendly transportation fuels. The DoD is offering an open invitation for all state and federal agencies, industry and academia to help us with this initiative.



Appendix

- **Points of Contact**:

Dr. Theodore Barna, Assistant Deputy Under Secretary of Defense for Advanced Systems and Concepts is the lead for this DoD effort. He can be contacted at Ted.Barna@OSD.mil.
Assisting Dr. Barna is Ted Sheridan, Director Clean Fuels Initiative Tedsherxxx@aol.com
Bill Harrison, Senior Advisor, William.Harrison@wpafb.af. mil.
The Army National Automotive Research Center leads programs to evaluate Fischer Tropsch Fuels. Patsy Muzzell Pat.Muzzell@us.army.mil.
DOE contacts: Shale Tony Dammer, Director Naval Petroleum and Oil Shale Reserves Anton.Dammer@hq.doe.gov
Coal: Lowell Miller, Director of Sequestration, Hydrogen and Clean Coal Lowell.Miller@hq.doe.gov
Edward Schmetz, Senior Program Manager, Hydrogen and Transportation Fuels, Edward.Schmetz@hq.doe.gov
Carl Bauer, Acting Director, National Energy Technology Laboratory, Carl.Bauer@netl.doe.gov
John Winslow, Program Manager Transportation Fuels and Chemicals John.Winslow@netl.doe.gov
Pamela Serino, Chief, Product Technology and Standardization, Pamela.Serino@dla.mil