COAL GASIFICATION AND LIQUEFACTION FOR ELECTRICITY GENERATION AND TRANSPORTATION

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The following tutorial is an introduction to the refereed and non-refereed 2007 Internet literature relating to the use of coal to replace natural gas for electricity generation and also imported or high-cost domestic oil for transportation applications. It is not an authoritative reference source without careful quantitative verification of all of the number appearing in this preliminary document.

INTRODUCTION

Coal has been used as a fuel since the Bronze Age (2000 to 3000 years ago) in many parts of the world, including England, as has been verified by examining remains of funeral pyres. Incidents of heavy air pollution associated with uncontrolled burning of the varieties of easily accessible coal types go back at least one thousand years and efforts to minimize theses occurrences have periodically resulted in the imposition of limitations for coal burning.

The name coal is used for a wide range of fuels with progressively decreasing levels of carbon concentrations which range from anthracite (which is nearly pure carbon) to semi-anthracite to bituminous coals of various ranks with decreasing heats of combustion per unit mass to sub-bituminous coals and to lignites and peat with minimal amounts of carbon and high water concentrations. In the US, recent annual use has been about 1 billion tones (I tonne=1000kg) of which upward of 90% was consumed for electricity generation. Even this heavy coal use has recently been surpassed by the consumption of 1.7 billion tonnes in the China-India region which is expected to consume 2.7 billion tonnes by 2025.

Another important use of coals is in metallurgical processing in the form of coke which is actually devolatelized coal.

Because of the variability of coals, resource and reserve estimates must be made with care as has been done in the US Geological surveys which classify the resources in terms of type, locations at defined depths, thickness of overlays, etc. Data of this type are often agglomerated to specify total barrels of oil equivalent in coal mixtures of various ranks. The needed operative qualifier for coal is “recoverable reserves,” i.e. recoverable resources with currently available technologies. These can usually not be specified accurately to more than two significant figures at best. The lack of precise knowledge has not prevented authors from giving estimates to 5 or even 6 significant figures. After rounding off to 3 significant figures, a July 2007 compilation in the Wikipedia gives a list of recoverable coal reserves for many countries with the following top 10 entries.

COUNTRY	RECOVERABLE COAL RESERVES (1999) in MILLIONS of TONNES
USA	250,000
RUSSIA	157,000
CHINA	115,000
INDIA	84,400

AUSTRALIA	82,100
GERMANY	66,000
SOUTH AFRICA	49,500
UKRAINA	34,200
KAZAKHSTAN	34,000
POLAND	22,200

According tot he US DOE, US coal reserves amount to about 1.081 trillion short tons which equal about 9.81 x 10^{14} kg or about 4,790 billion barrels of oil equivalent. At the present rate of annual oil consumption, the specified coal reserves would last about 285 years. The current annual US consumptions of NG and oil are 51 and 76 millions of barrels of oil equivalent, respectively.

The investment promise of coal use has been well recognized in the US. As of July 3, 2007, the year-to-date returns for 4 selected large coal companies ranged from 8.4% to 48.8% with an average of 24.7% as compared with the returns for 10 "green" companies such as GE, AA, DUK, CAT, PCG, etc. which ranged from –8.7% to 39.2% and averaged only 7.7%. This type of compilation is, of course, biased by the selection of the companies involved.

INTEGRATED GASIFICATION COMBINED CYLCE SYSTEMS (IGCCs)

The currently preferred choice among the technologies for coal gasification involves IGCC systems. With these systems, coal is converted into a gas composed primarily of CO and hydrogen. The decomposition products are determined by the mixture of coal, oxygen and steam used in the gasifer. The movement of coal may be controlled in the gasification section by using a fixed coal bed, a fluidized coal bed, or an entrained-flow coal system. Oxygen-enriched air or pure oxygen are generally used as the oxidizing medium in IGCCs and also in pressurized fluidized-bed combustion systems. Both of these systems contain gas turnbines and steam turnbines for power generation. This type of arrangement is referred to as a combined-cycle system. Their overall efficiencies have been improved in recent years and now generally fall into the low end of the range 42 to 52%. The fuel flowing out of the gasifier must be cleaned very thoroughly by removing sulfur compounds and particulates. Because hot-gas clean-up systems remain unavailable even though they have been under intensive development, the gases must be cooled before clean-up, which increases costs and reduces the overall efficiencies. Acceptable systems reduce sulfur dioxide levels by more than 99% and NOx to less than 50ppm.

An important IGCC demonstration program for a 100 MWe plant ended at Cool Water in California in 1989. More recent studies supported by the DOE Clean Coal Technology Program involve an 80 MWe effort using Kellogg technology and the Tom Creek 107 MWe IGCC system based on IGT’s U-gas technology which has been developed especially for use with Indian and Chinese high-ash coals. Three IGCC plants using petroleum coke were put into operation during the late 1990s in Italy. IGCC cost projections are US $1200 to $1400 per ton and thus remain higher than air-blown and oxygen-blown gasifiers. Representative operating systems and their performance are described at http://www.geocities.com/pemnq/igcsscran.html?200711. The EPRI program descriptions at http://www.epri.com/portfolio/product.2.spx?id=3415 and is noteworthy for both its low program budget of $9.5 million for 2008 and high claimed financial leverage factor of $53 to $1. There is a substantial gasification program in India. For a laudatory summary of this activity, see http://www.ccsd.biz/factsheet/igcc.cfm

For DOE data, see
http://www.fe.doe.gov/programs/powersystems/gasification/index.html

Company reports have been released by the Business Communications Company, Inc., on the Internet. For a discussion on “Democrats Plan to Subsidize Coal Industry,” see http://www.maketoracle.co.uk/Article_1285.html

CONVERSION OF COAL TO LIQUIDS (CTL)

Franz Fischer and Hans Tropsch invented CTL in Germany during the 1920s; their procedure is known as Fisher-Tropsch synthesis. Extensive use was made of this technology in Germany during World War II. During the Apartheid years, South Africa used FT to make diesel fuel and Sasol became an established major factor in CTL with world-wide efforts including Gulf Coast plants in the US during the seventies and eighties which were terminated when world oil prices declined. The present production of diesel fuel from coal in South Africa is about 150,000 bpd. US Congress proposals under consideration include a $0.51 tax credit per gallon of CTL until 2020 with additional subsidies if crude oil costs drop below $40 per barrel. The USAF may offer long-term contracts for about 1 billion gallons of CTL per year, which is similar to current subsides for ethanol. CTL systems yield cleaner fuels than conventional diesel. The large coal company Peabody Energy (Wall Street symbol: BTU) is reputed to be actively engaged in lobbying for more CTL. In May of 2007, the China Daily reported that the first coal liquefaction research center in China had been set up in Shanghai by three industrial companies, namely, the Shanghai Electric, Shenhua and Shanghai Huayuan Groups with an initial investment of about 12 million US dollars. The Center will explore direct and indirect coal-liquefaction technologies.

Many more articles may be found on the Internet on world-wide efforts to truncate the costs of imported oil through the development of coal-to-liquid programs. Protective measure will be needed that remain in place for the long term because imported oil can be sold at a profit at much lower prices than current prices for CTL and even temporary interruptions of the CTL programs may cause long-term delays with resulting significant costs to US and other consumers with long-term dependence on costly foreign or domestic oil supplies. The past performance of subsidy activities has not helped much because the subsidies for new technologies were not maintained during time intervals that were judged to be non-crisis periods.

The hazards associated with coal recovery from underground mines are recalled for us by repeated tragic accidents involving mines all over the world. For this reason, it is regrettable that in sita recovery through underground coal gasification was abandoned by the US Department of Energy when an active program waste terminated around 1990 at the Livermore National Laboratory.

STATUS SUMMARY

2006 WORLDWIDE COAL USE: 5.3 billion mt with 75% used for 40% of world-wide electricity generation

China, India and adjacent countries used 1.7 billion mt with projected growth by 2025 to 2.7 billion mt.
Worldwide coal use has recently been growing at about 25% in 3 years.
The best efficiency for electricity generation has averaged about 35% but should reach about 45% with higher T, p.
World coal reserves at current use rates will last about 300 years (British Petroleum estimate).

Coke from low-ash, low-sulfur bituminous coal (formed at 800 to 1000 degrees C) is the fuel of choice in smelting iron ore in blast furnaces; by-products include coal tar, ammonia, light oils, “coal gas”.

Coal gasification with steam and oxygen is used to produce syngas (hydrogen + carbon monoxide +…) which is comparable to NG

Coal Liquefaction is accomplished via the Fischer-Tropsch Synthesis (used in Germany and then promoted worldwide by Sasol (South Africa). The process involves coal gasification to make CO + H_2; on passage over a suitable catalyst, light HCs are formed.

These light HCs, in turn, produce gasoline or diesel fuel or methanol in the presence of suitably selected catalysts; methanol may be converted to gasoline by using, for example, the Mobil M-gas process.

Other processes for making liquid fuels are the Bergius Process (developed in Germany during the nineteen twenties) and the Gulf Oil Solvent Refined Processes SRCI and SRC II (developed during the 1960s and 1970s). In both of these processes, coal is gasified to light hydrocarbons. In the Bergius process, liquid fuels are then made by further reaction with hydrogen; in the Gulf oil processes, liquid fuels are made by direct conversion of light hydrocarbons to fuels.