Newer gasification and liquefaction technology

As Fig. 12.5 shows, the costs of natural gas, which was the favorite fuel for new electric turbines, far outstripped that of coal in the late 1990s and early 2000s. The very low energy prices in the early 1990s forced the coal producers to become much more efficient or go under, and new, cheaper, methods of mining were adopted. An additional motivator is the dwindling of easily-extracted oil and gas (the easiest resources to obtain are exploited first). Not only are such resources easier to locate, they are less energy-expensive to exploit.\(^{(1)}\) For example, Hall et al. estimate that the energy returned on energy invested ratio (known as EROI) was 100 to 1 early in exploitation of oil, but now hovers around 17, a factor of 6 smaller.\(^{(1)}\) The EROI is important because the exploitable resources must have EROI substantially greater than 1 to be economically feasible. Reporter W. R. Long quoted Stephen F. Leer, chairman of the National Mining Association and chief executive of Arch Coal, Inc., saying “People have become very efficient in their mining techniques, and now you’re seeing those efficiency drives spill over.”\(^{(199)}\) Coal became the better economic choice for utility executives.

Since coal still powers well over half the electric generators in the country, and since it is relatively cheap, it is natural for utilities to try to pursue ways to use coal to produce more electricity. Additionally, the gasification processes are the best possibility to reduce emissions of carbon dioxide from coal-powered electricity, because the coal is made into a gas before it is burned. This allows the carbon to be sequestered before it has burned into carbon dioxide.

Difficulties have occurred with proven processes (old technology), for example, agglomeration of pulverized coal and large volumes of waste. These difficulties led the U.S. Bureau of Mines as well as private corporations to research on newer types of
Gasifiers may generally be classified as gravitating-bed, fluidized-bed, or suspension, depending on whether they work with lump coal, crushed coal, or pulverized coal, respectively.

In the gravitating-bed gasifier, new coal enters from the top into a region of humidified (steamy) air that rises from the bottom. Oxygen is removed from the air in a combustion zone in the coal column, the residue of which is a powdery carbon-free ash that falls into a grate. The degree of humidity controls the rate of reaction of steam with carbon, and carbon with carbon dioxide. The Lurgi process, mentioned previously, is a gravitating-bed gasifier in which steam and coal react at 20 times atmospheric pressure.

In fluidized-bed gasifiers, rising gases buoy the granular coal as it burns, assuring uniform temperatures. In the Ignifluid process (developed in France during the 1920s), the crushed coal travels on a moving bed which carries off the self-adhering ash.\(^{(195,208)}\) Such gasifiers generally supply gas at a much higher rate than gravitating bed gasifiers, but they do not burn the coal so thoroughly.

In suspension gasifiers, the finely pulverized coal reacts in a dilute suspension with oxygen and steam at atmospheric pressure, and the ash falls as clinkers (glassy cinders). The Bi-Gas process is a two-stage suspension gasifier in which the reaction of coal and...
steam takes place at about 900 °C and the synthesis gas from the lower chamber is gasified further with oxygen and steam at about 1500 °C. Less carbon dioxide is produced in the latter process.

After the coal has produced some gas, the subsequent processes involve one of several alternate methods: pyrolysis, or destructive distillation; gasification followed by synthesis; hydroliquefaction; and solvent extraction. Examples of synthesis are the Fischer-Tropsch process for synthetic fuel liquid (one of the oldest processes known) and the Mobil process for making methanol from synthesis gas by passage over an acidic catalyst. An example of hydroliquefaction is the Ashland H-coal process in which coal is liquefied by treatment with hydrogen at ≈ 450 °C and 70 to 200 times atmospheric pressure. The hydrogen is not especially cheap, and it takes additional energy to increase the pressure so much above atmospheric. Nevertheless, the cost has fallen by 60%, and is now about twice the price of oil. The future of liquefaction is promising. Examples of solvent extraction are the Exxon donor solvent and the Gulf-SRC-II processes, in which coal is mixed in a solvent to form a slurry, hydrogen is added, and the coal is then gasified. The relative advantages and disadvantages of these various processes are still under study.

The Northside Generating Station, the world’s biggest circulating fluidized-bed plant was built by the Jacksonville Electric Authority. It converted a conventional coal plant, more than doubling electric output while decreasing emissions. While a triumph of clean coal technology, the plant still emits much more than a comparable gas-fired plant.
The Sasol plant

The largest installation in the world for production of liquid fuel from coal is operated by Sasol, the South African oil company. When South Africa was an international pariah, there was an internal political reason to use an uneconomic process to produce gasoline. Sasol uses Lurgi dry-ash gasification to produce synthesis gas, which is re-formed with oxygen and steam over a nickel catalyst and then liquefied by the Fischer-Tropsch process involving powdered iron as a catalyst.\(^{(171)}\) This process was first used by the Germans in World War II to make up for shortfalls in supplies of petroleum, since Germany has (as does South Africa) large domestic coal reserves. The Sasol process produces gas that is composed of 60% carbon monoxide (CO) and hydrogen (H\(_2\)), 29% carbon dioxide (CO\(_2\)), 9% methane (CH\(_4\)), 1% argon and nitrogen (A, N\(_2\)), and 0.5% hydrogen sulfide (H\(_2\)S).\(^{(171)}\) The gas composition is not atypical.\(^{(207)}\) The Luigi process, in addition to its thermal inefficiency, has the drawback that it produces tars as byproducts and that it wastes much of the carbon.

Other gasification processes promise great possibilities for reduction of pollution. Contamination may be controlled at the source before dilution in the atmosphere. In processes using air, improved rates of flow allow combination at lower temperatures, thereby lowering nitrogen oxide emissions; sulfur combustion is suppressed, and sulfur captured readily, before the gas is burned.\(^{(201,208)}\)

The Texaco process

The Texaco process has led to two commercial ventures: a process by which Tennessee Eastman is making acetic anhydride from syngas instead of oil\(^{(201)}\) and the Cool Water Gasification Plant developed to supply Southern California Edison with electricity.
Acetic anhydride is used in large quantities in the manufacture of many organic acetates, for example, vinyl acetate. The plastics are used for many purposes, including use as fibers. The Eastman plant alone is to produce about 250 kt of acetic anhydride per year. Acetic anhydride is made from ketene (formed by pyrolysis of acetic acid) and acetic acid. The process, based on organic compounds, is expensive, time-consuming, and produced unwanted byproducts. The Texaco process uses coal to produce synthesis gas (CO and H₂); water is added to shift the proportions of CO and H₂, and methanol is formed; methanol is reacted with CO to make methylacetate; then the methylacetate is reacted with CO to make acetic anhydride. This process also may be used to yield vinyl acetate through hydrocarbonylation of the methylacetate and thermal cracking.\(^{201}\)

**The Great Plains Coal Gasification Project**

The other commercial-sized gasification and liquefaction project, the Great Plains Coal Gasification Project, at Beulah, North Dakota, is currently producing. It obtains product price supports ($800 million) from the Synthetic Fuels Corporation. The current gas sale price is only about 60% of the amount needed to keep it open. Even though the Department of Energy has sold the plant, political pressures are at work to subsidize it through the Department of Defense (DOD). Legislation was written to direct the DOD to purchase 10,000 barrels per day of coal-based jet fuel from the plant (about half the plant’s capacity).\(^{209}\) This gasification plant has made North Dakota the third-largest destination for western coal.\(^{178}\)

**Onsite gasification**

Another proven technique involves on-site production of gas at the coal field. The U.S. Bureau of Mines ran an experiment near Hanna, Wyoming, in which sixteen wells were
drilled over a 10-hectare area into a coal seam 10 meters thick, and which was then fractured hydraulically. Air was injected far from the center, and gas rose at the center installation. In this experiment about 25 tonnes of coal a day was gasified; and the well produced 70,800 m$^3$ [2.5 Mft$^3$] per day of 5.27 to 5.64 MJ/m$^3$ gas. The gas produced was 5% methane, 10% carbon monoxide, 15% hydrogen, 15% carbon dioxide, and 54% nitrogen.$^{(192)}$ Of course, the latter two gases cannot burn.

This technique seems feasible where there are deep coal seams (where underground mining is hazardous, and only about a quarter of the coal is presently recoverable), or for coal seams that are impracticable to mine for various reasons. We might note here that some deep beds being mined produce 0.34 Mm$^3$ [12 Mft$^3$] of methane per day (5 m$^3$ per tonne of coal in place).$^{(192)}$

The town of Centralia, Pennsylvania, has had to be abandoned because of a two-decade-long fire in the coal seam underlying the town. This gives evidence to the feasibility of extended burning in situ.

**Liquid fuel from coal**

Some have suggested making liquid fuels from natural gas in ways similar to the those adopted for coal.$^{(210)}$ This seems foolhardy, however, as the supply of natural gas is not that large (unless the clathrates can be utilized). It is needed to heat homes and run electric power facilities nationwide.
Increasing coal’s grade

The company KFx, Inc. takes local Wyoming coal of low heat of combustion and low sulfur levels and removes the water. It then sells the resulting modified coal at a price similar to the price of the higher heat of combustion (but sulfur-rich) eastern coal. The company has invested $40 million to build the plant to process 0.5 Mt of coal a year.\(^{(211)}\)