GASIFICATION BACKGROUND

ADVANTAGES AND EFFICIENCY OF GASIFICATION

Clean Power Generation

Clean power generation, through integrated gasification combined cycle (IGCC) and repowering older coal-based plants, is the primary market for gasification technology into the future. Initial market entry will primarily use coal, or refinery bottoms and petcoke, which offer economic advantages and are a competitive technology even at today's natural gas prices. Coal-based IGCC power generation will follow and is predicted to achieve a large electric market share due to its domestic abundance and relatively low, stable price. IGCC is predicted to be the ultimate, dominant market for gasification given a strong power market.

The EIA's *Annual Energy Outlook 2012* predicts total electricity sales will increase from 4,152 billion kWh in 2010 to 5,004 billion in 2035, a 20.5% increase (average rate of just under 1% per year). Coal-fired generation is predicted to increase from a 2012 level of 1,851 to 1,897 billion kWh by 2035, notwithstanding the 45 GW of capacity expected to retire in this timeframe. This represents a large market potential for IGCC.

Puertollano IGCC Power Plant

Waste disposal and recycling is another potential clean power generation market. Environmentally, gasification is superior to incineration, but the technology does require more research and development before its market strength can be realistically assessed. Work on gasification of highly toxic substances into salable by-products is also a promising technology.

Power generation is conducive to co-generation of other products. Power can be generated during peak demand, but then production can be diverted to other products during lesser-use periods.

Clean Energy Conversion

Clean energy conversion refers to the conversion of one energy source (typically coal or biomass, although there are many potential feedstocks) into another, usually for convenience or further use. For example, coal is not practical to power an automobile, but gasoline is.

Synthesis gas (syngas) from gasification can be used as a basis for producing clean transportation fuels, chemicals, and gaseous fuel for fuel cells. Chemical production through syngas is already a proven technology, with almost 29 GWth capacity installed by 2010, but it is the generation of ultra-clean transportation fuels production that is expected to have the greatest market growth in the near term. Gasification and subsequent synthesis of fuels has the potential to meet a growing need for low-sulfur, high-quality diesel. Gasification-derived syngas is the feedstock for a variety of additional products including methanol and other chemical and precursors. The market for methanol and other hydrocarbons for use as blending stock should grow, especially as cleaner fuel regulations increase. The market for gaseous fuels from coal, like SNG, has been proven by the Great Plains Synfuels Plant, while H_2 for use in highly efficient fuel cells is expected to develop as supporting technology and fuel cells themselves improve.

Gasification Versatility

Gasification vs. Combustion

Gasification differs from more traditional energy-generating schemes in that it is not a combustion process, but rather a conversion process. Instead of the carbonaceous feedstock being wholly burned in air to create heat to raise steam which is used to drive turbines, the feedstock to be gasified is combined with steam and limited oxygen in a heated, pressurized vessel. The atmosphere inside the vessel is starved of oxygen, and the result is complex series of reactions of the feedstocks to produce syngas. The syngas can be cleaned relatively easily, given the much lower volume of raw syngas to be treated compared to the large volume of flue gases that need to be treated in conventional post-combustion cleaning processes. In fact, gasification processes used today are already able to clean syngas beyond U.S. Environmental Protection Agency (EPA) requirements (current and proposed), as demonstrated by currently commercial chemical production plants that require ultra-clean syngas to protect the integrity of expensive catalysts. The clean syngas can be combusted in turbines or engines using higher temperature (more efficient) cycles than the conventional steam cycles associated with burning carbonaceous fuels, allowing possible efficiency improvements. Syngas can also be used in fuel cells and fuel cell-based cycles with yet even higher efficiencies and exceptionally low emissions of pollutants.

Feedstocks

An advantage of gasification is its applicability to a variety of feedstocks, either singly or in combinations. Almost any carbonaceous substance can be gasified: fossil fuels such as coal (varying in rank) and oil, refinery waste, byproducts such as asphalt or black liquor, biomass (which is any kind of agricultural waste such as corn stover, or various crops), or even sewage, plastics, and municipal solid waste.

Efficiency Advantage of Gasification

Gasification has the potential for highly efficient power generation. While a conventional subcritical pulverized coal (PC) power plant has a typical plant efficiency of about 35% (see a reference discussing how efficiencies are calculated and comparing efficiencies of various types of power generation plants), an integrated gasification combined cycle (IGCC) power plant can have a plant efficiency of greater than 43% depending on the gasification and heat recovery technologies employed and the degree of plant integration with other processes, like air separation, for example. When coupled with other advanced technologies under development, like hydrogen turbines and solid oxide fuel cells, a gasification power plant can have efficiencies as high as 60%—a very substantial gain over conventional technologies.

Meaning of Efficiency

A typical plant efficiency value reveals how much of the energy contained in a fuel (coal or natural gas, for example) is output as a useful product, often electricity. The efficiency value also tells of a plant's *inefficiencies*, like wasted heat or energy intensive subsystems (gas cleaning, for example).

Efficiency is ultimately limited by thermodynamics. Heat loss and friction typically account for most of a gasification system's inefficiencies. Heat exchangers are used to try to reclaim and reuse heat lost during temperature and phase changes, but there are always losses to the environment—and any heat that cannot be reclaimed lowers the system efficiency.

Improved integration of systems like the gasifier and the turbine generators in IGCC can increase efficiency. Reducing the energy requirements of any subsystem (i.e., the gas cleaning system) increases the plant efficiency as a whole.

Energy Conversion Process Efficiency

Efficiency, which is sometimes represented by the lower case Greek letter Î· (eta), is generically expressed mathematically: $\eta = E_{out} / E_{in}$, or in other words, what percentage of the energy put in is converted to product (output) energy.

The energy input by a fuel is typically measured in two different ways: a higher-heating value (HHV) or a lower-heating value (LHV).

1. The HHV—also known as the gross calorific value of a fuel—is the amount of heat released following total combustion and *after* the products have returned to the starting reference temperature (25°C).
2. The LHV—also known as the net calorific value of a fuel—is the amount of heat released upon total combustion (starting at 25°C) and the products temperature has cooled to 150°C.
3. The difference in temperature at the end of the measurement means the LHV does not take into account heat recovered from the condensation of water (which returns to liquid state below 100°C), while HHV does.

The *heat rate* measures how efficiently a power plant or other energy conversion process uses heat and is a common metric describing the efficiency of power plants. A plant that uses 450,000 lbs/hour of bituminous coal to produce a net 630 MWe would have a heat rate of 8,300 Btu/kWh (on an HHV basis). Heat rate is a like an inverted efficiency, it tells how much heat is needed (energy in) for power generated (energy out). Efficiency, in general, is the opposite of this. The comparison of gasification and pulverized coal power plants compares the heat rates of gasification and other energy conversion plants.

References/Further Reading

- How Coal Gasification Power Plants Work - *U.S. Department of Energy*
- Thermochemical Conversion Processes - *EERE*
- What is Gasification? - *Gasification Technologies Council*
- Theory of Gasification - *Food and Agriculture Organization of the United Nations*

Gasification Background

- Markets for Gasification
- Drivers for Gasification Technology
- **Advantages and Efficiency of Gasification**
- Challenges for Gasification
- History of Gasification
  - Beginnings
  - Applications for Light and Heat
  - Gasification for the Development of Liquid Transportation Fuels
  - Post WWII Development
  - Renewed Interest in the New Millennium