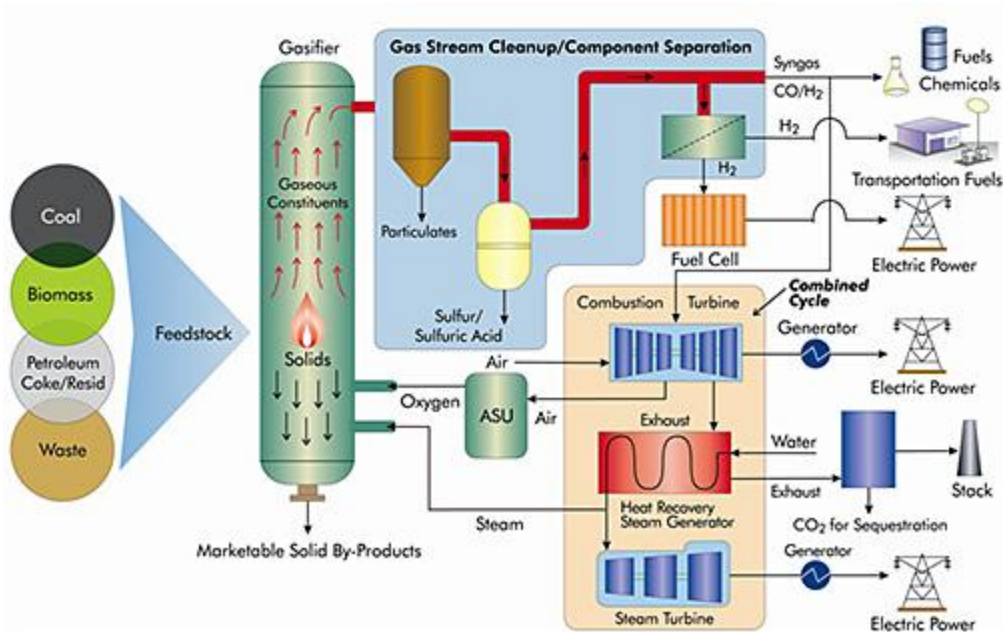
BEGINNINGS

Gasification has grown from a simple conversion process used for making "town gas" for industrial lighting to an advanced, multi-product, carbon-based fuel technology of today and tomorrow. Gasification was first used commercially in the 1800s for industrial and residential heating and lighting. As the use and distribution infrastructures for electricity and natural gas evolved, town gas use declined and gasification development paused. However, history has shown that the technology is revisited when access to natural gas, oil and petroleum products are limited. Today, gasification technology development is enjoying a renaissance as a means for producing electrical energy, synthetic natural gas, liquid fuels or chemical products from coal, biomass, or other carbon containing materials under increasingly stringent environmental constraints.

Gasification is a technological process that uses heat, pressure, steam, and often oxygen to convert any carbonaceous (carbon-based) raw material into synthesis gas. Syngas, for short, is so called because of its history as an intermediate in the production of synthetic natural gas. Composed primarily of the colorless, odorless, highly flammable gases carbon monoxide (CO) and hydrogen (H_2), syngas has a variety of uses. The syngas can be further converted (or shifted) to nothing but hydrogen and CO_2 by adding steam and reacting over a catalyst in a water-gas-shift reactor. When hydrogen is burned, it creates nothing but heat and water, resulting in the ability to create electricity with no carbon dioxide in the exhaust gases. Furthermore, hydrogen made from coal or other solid fuels can be used to refine oil, or to make products such as ammonia and fertilizer. More importantly, hydrogen enriched syngas can be used to make gasoline and diesel fuel. Polygeneration plants that produce multiple products are uniquely possible with gasification technologies.

Gasification offers an alternative to more established ways of converting feedstocks like coal, biomass, and some waste streams into electricity and other useful products. The advantages of gasification in specific applications and conditions, particularly in clean generation of electricity from coal, may make it an increasingly important part of the world's energy and industrial markets. The stable price and abundant supply of coal throughout the world makes it the main feedstock option for gasification technologies going forward. The technology's placement markets with respect to many techno-economic and political factors, including costs, reliability, availability and maintainability (RAM), environmental considerations, efficiency, feedstock and product flexibility, national energy security, public and government perception and policy, and infrastructure will determine whether or not gasification realizes its full market potential.

The graphic below is a representation of a gasification process for coal, depicting both the feedstock flexibility inherent in gasification, as well as the wide range of products and usefulness of gasification technology.



Discovery and Earliest Experimentation

- In 1609, Jan Baptista Van Helmont, a Belgian chemist and physician, discovered that gas could be produced from heating wood or coal.[1] Following this discovery, several others aided in developing and refining the gasification process:
- 1669: Thomas Shirley performs various experiments with carbonated hydrogen.
- Late 1600s: John Clayton experiments with capturing gas produced from coal.
- 1788: Robert Gardner becomes the first to obtain a patent dealing with gasification.
- 1791: John Barber receives the first patent in which "producer gas" was used to drive an internal combustion engine.
- 1798: Biomass gasification is first conceived when Philippe Lebon led efforts to gasify wood.

William Murdoch (1754-1839)
Reproduction of a portrait by John Graham Gilbert in the City Museum and Art Gallery, Birmingham (public domain)

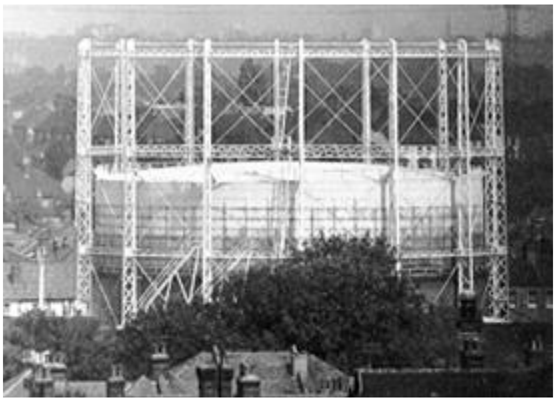
Applications for Light and Heat

In 1792, Scottish engineer William Murdoch first realized the commercial potential of heating coal in the absence of air to produce gas. Murdoch used this gas to provide lighting in his home while refining his manufacturing method.[2] He collaborated with his employers, Matthew Boulton and famous steam engine manufacturer James Watt, to provide industrial gas lighting throughout England by 1798. In 1807, "town gas" began to be used for street lighting, and by 1816 most of London was using the gas.[1] Some important milestones for gasification technology in this period were:

- In 1804, coal gas was first patented for lighting by Freidrich Winzer.[2]
- London and Westminster Gas Light & Coke Company performed the first public display of gas lighting by illuminating Westminster Bridge on New Year's Eve in 1813 using "town gas" via wooden pipes.
- The Baltimore Gas Company became the first gasification company in the United States in 1816, providing town gas for street lighting.
- Following its introduction in Baltimore, street lighting with town gas spread through the Eastern United States very rapidly, including to Boston in 1821, New York in 1823 and Philadelphia in 1841.
- Prior to World War II approximately 20,000 gasifiers were operating in the United States alone.[1]

Before long, nearly every major urban area had its own gas works to convert coal into gas for lighting, heating and cooking fuel.

Gasification continued to fill a significant role as an energy supply technology until advancements in safer electric lighting by Thomas Edison in the 1880s forced town gas out of the interior lighting market. Increasing natural gas resources and infrastructure improvement in the early 1900s provided a low-cost alternative to town gas for heating and cooking applications, reducing gasification to use in areas without access to natural gas.



Sutton Gas Holder
This tank was used for storage of town gas prior to distribution to consumers. The volume of the tank could be adjusted to allow for varying levels of gas production and consumption. (Courtesy of the London Borough of Sutton)

Workers at Sutton Gas Works
Early gasification involved shoveling of coal into large sealed vessels called retorts. The coal was then heated to produce town gas, tar and coke. The workmen here were employed to shovel coal into the retorts. (Courtesy of the London Borough of Sutton)

Gasification for the Development of Liquid Transportation Fuels

The next major stage of development in gasification began in Germany in the years preceding World War II, when processes were developed to refine syngas produced by gasification into liquid fuels.

By the 1920s, Germany had realized its dependence on imported petroleum as a result of the blockades of World War I. The war had also depleted Germany's economic ability to purchase foreign oil. Amid world wide rumors that petroleum reserves would soon run out, Germany decided to develop a means for producing liquid petroleum fuels from their substantial coal reserves.

German Synthetic Fuel Plant
Synthetic fuel plant in Germany after being bombed during WWII.
(source: Fischer-Tropsch Archive)

During the years 1910 to 1925, German Friedrich Bergius developed a process of high pressure coal hydrogenation or liquefaction; known as the Bergius process, to convert coal into liquid fuels. German scientists Franz Fischer and Hans Tropsch developed a second process for this purpose which now takes their name, theFischer-Tropsch process, in which syngas produced from coal could be processed into liquid fuels.[1] By the time World War II ended in 1945, 12 coal hydrogenation plants and nine Fischer-Tropsch plants were constructed in Germany.[2]

Post WWII Development

Following World War II, many countries had access to large supplies of low-cost gasoline and diesel fuel resulting in a decreased role for gasification as a means of energy production. However, South Africa's political and geographic isolation led to the development of a large coal-to-liquid fuels industry. In 1950, the South African government sponsored the South African Coal, Oil and Gas Corporation Limited's (SASOL) construction of a gasification plant (SASOL I) which used both American and German processes to produce diesel fuel, medium octane gasoline, liquefied petroleum gas, and a number of chemicals. Following operational improvements to increase plant efficiency and economics, processes were developed to produce synthetic rubber, fertilizers and other secondary chemicals.[1]

Sasol I
Gasification plant in Sasolburgh, South Africa
(source: Sasol)

South Africa continued to expand its gasification facilities with the construction of Sasol II in 1980 and Sasol III in1982, resulting from an oil crisis which threatened to decrease its oil supply from the Middle East.[1]

In the United States, interest in gasification was renewed in the 1970s due to natural gas shortages and the decreased access to petroleum products in part due to the Arab Oil Embargos in 1973 and 1979. This resulted in government funded research on gasification technology for both power and liquid fuels production. In 1984, the first integrated gasification combined cycle (IGCC) demonstration near Barstow, California, at the Cool Water IGCC demonstration project began producing electricity through coal gasification.[2]

Using Federal loan guarantees, a consortium of energy companies built the Great Plains Gasification Plant, which produced synthetic natural gas from North Dakota lignite beginning in 1984. However, the collapse in world oil prices in the mid 1980s again diverted attention away from gasification because cheaper petroleum supplies were once again available.[3]

In 1983, Eastman Chemicals commercialized a first-of-the-kind coal gasification plant in the United States producing chemicals. The plant was expanded in the early 1990s. Over the last 25 years of operation, Eastman has successfully demonstrated both the performance and economics of the plant.

Renewed Interest in the New Millennium

In the 1990s, with oil prices on the rise, volatility in the Middle East again increasing, and new awareness of the environmental impacts of energy production, American and European support for cleaner production of electricity from coal and other fuels again revived interest in gasification technology. Backed by public funding, the feasibility of IGCC was proven by various demonstration projects to a point where commercial developers began reconsidering gasification applications.[1] Texaco gasification technology (now owned by GE) was used in building the Polk Power Station near Mulberry, Florida, in the early 1990s, becoming the Nation's first "greenfield" (built as a brand new plant) IGCC power station. In 1994, an IGCC plant was commissioned in Buggenum, Netherlands, based on technology developed by Shell. Technology developed by Dow Chemical (now owned by ConocoPhillips) was implemented at the Wabash River Coal Gasification Repowering Project near Terre Haute, Indiana, becoming the first full-size commercial “re-powering” IGCC plant in the United States in 1995.[2]

Following up on the successes of the 1990s, more and more gasification plants began to be built for production of fertilizers and chemicals, synthetic natural gas and hydrogen, and liquid fuels. NETL's 2010 World Gasification Database[3] (Oct 2010) shows there are 144 operating gasification plants worldwide with a total of 427 gasifiers in operation (including spares) in 27 countries.

Polk Power Station Tampa Electric's Integrated Gasification Combined Cycle Power Plant (source: Tampa Electric)

Today and Tomorrow
Many countries and enterprises are focusing extensive programs on performing the research, development, and demonstration necessary to maximize the potential for gasification in the future. A full 400 years after Van Helmont's discovery, efforts to better understand and improve the gasification process continue – ranging from DOE's R&D activities in the area, to gasification development around the world.

Waste to Energy

The financial and environmental costs associated with the traditional waste management process of collecting waste for deposit in a landfill are significant. Hauling waste to a landfill is expensive, produces vehicle emissions that degrade air quality and contributes to traffic congestion. Once at the landfill, the waste decomposes, releasing greenhouse gases. Utilizing available and proven technology to recover energy from organic waste avoids many of these costs. Processed properly, organic waste becomes a resource and a waste-to-energy (WTE) power plant becomes a clean, reliable source of renewable energy.

A WTE project is more than forcing a "one-size-fits-all" technology onto a community. There are considerations beyond the technology that are equally important; these projects often represent a dramatic shift in city or regional waste management and energy planning. NuEnergy's first step in project development is coordinating with the local community and conducting a feasibility study to identify local conditions, including waste stream characteristics, other available renewable energy resources and unique local issues that need to be addressed. The result will be a project that delivers the best value to the community.

WTE Basics

Organic waste deposited in a landfill decomposes over time, releasing a mixture of greenhouse gases into the atmosphere. Gasification controls and accelerates the natural decomposition process to create synthesis gas (syngas), which is used to generate power. This technology is not new; in the mid-1800's many large cities used gasification to produce the gas used for street lighting.