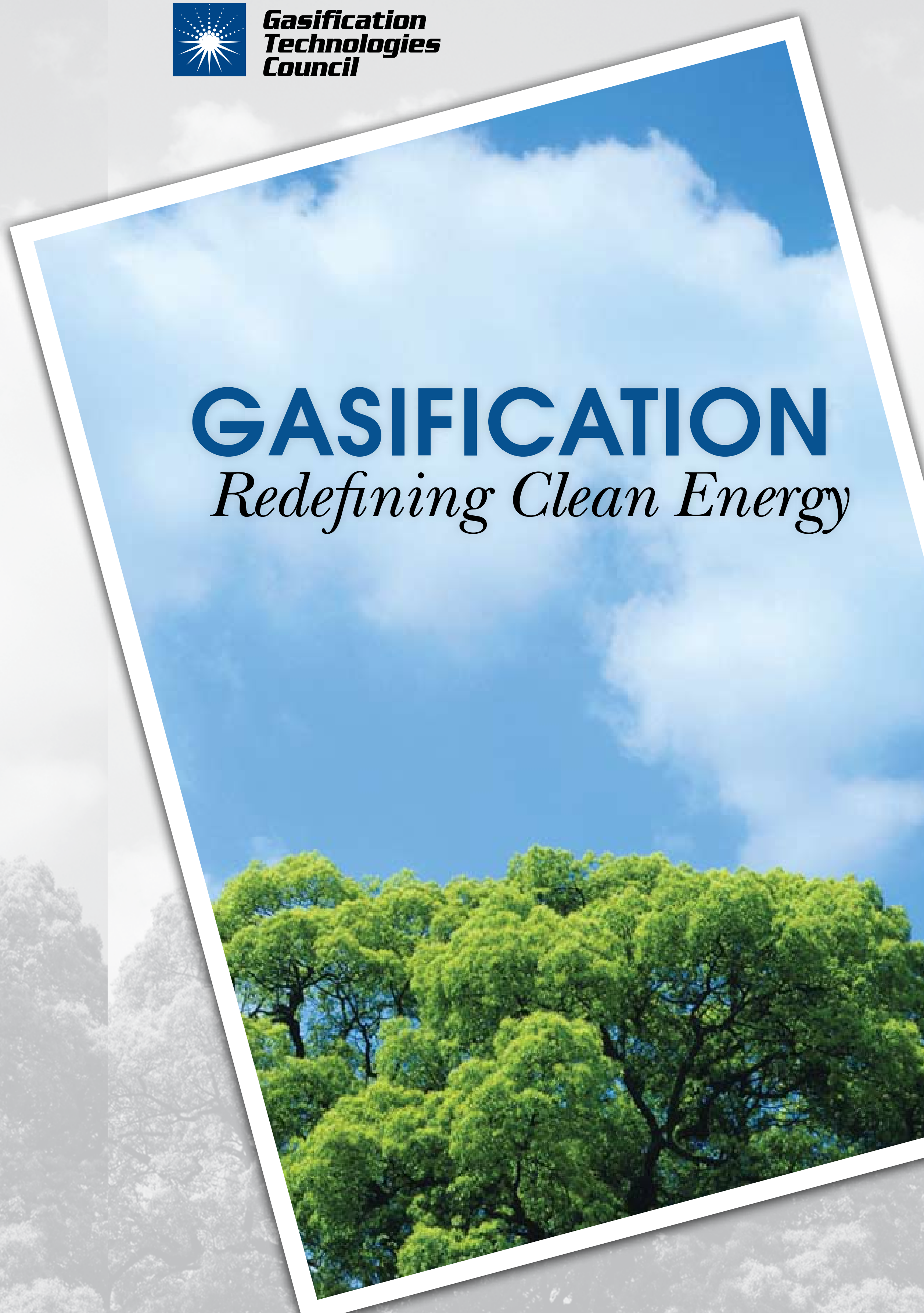
Gasification Technologies Council



GASIFICATION
Redefining Clean Energy

Gasification Technologies Council

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GASIFICATION AT A GLANCE

WHAT IS GASIFICATION?

Gasification is a proven manufacturing process that converts hydrocarbons such as coal, petroleum coke (petcoke), and biomass to a synthesis gas (syngas), which can be further processed to produce chemicals, fertilizers, liquid fuels, hydrogen, and electricity. (Gasification is not a combustion process.) Gasification is a flexible, commercially proven, and efficient technology that produces the building blocks for a range of high-value products from a variety of low-value feedstocks.

HOW DOES GASIFICATION WORK?

A hydrocarbon feedstock is injected with oxygen and steam into a high temperature pressurized reactor until the chemical bonds of the feedstock are broken. The resulting reaction produces the syngas. The syngas is then cleansed to remove impurities such as sulfur, mercury, particulates, and trace minerals. (Carbon dioxide can also be removed at this stage.) The clean syngas is then used to make either a single product such as fertilizer or multiple products such as hydrogen, steam, and electric power.

WHICH INDUSTRIES USE GASIFICATION?

Gasification has been used commercially around the world for more than 50 years by the chemical, refining, and fertilizer industries and for more than 35 years by the electric power industry. There are more than 420 gasifiers currently in use in some 140 facilities worldwide, with 19 plants operating in the United States. Gasification is also available to help in the production of oil from the vast Canadian oil sand deposits and substitute natural gas from America's abundant coal resources.

WHAT IS AN IGCC POWER PLANT?

An Integrated Gasification Combined Cycle (IGCC) power plant combines a gasification system with a modern, highly efficient "combined cycle" electric power system (consisting of one or more gas turbines integrated with a steam turbine). IGCC power plants are successfully operating worldwide and have been operating commercially in Indiana and Florida for more than a decade.

WHAT ARE THE ENVIRONMENTAL BENEFITS OF GASIFICATION?

Gasification enables the use of domestic coal, petcoke, and biomass to produce electricity with significantly reduced environmental impacts compared to traditional combustion technologies:

Because the syngas is cleaned before combustion, gasification plants produce significantly fewer quantities of criteria air pollutants such as nitrogen oxides (NO_x) and sulfur dioxide (SO_2).

Gasification enables the recovery of available energy from low-value materials (such as petcoke and municipal solid waste), thereby reducing both environmental impacts and disposal costs.

The byproducts from gasification (sulfur and slag) are non-hazardous under federal law and are readily marketable.

Gasification plants use significantly less water than coal combustion plants, and can be designed as zero-liquid water discharge facilities.

Carbon dioxide (CO_2) can be captured from a gasification-based plant using commercially proven technologies prior to combustion of the synthesis gas in the gas turbines, making it the lowest cost, most efficient way of capturing CO_2 from a fossil-fuel based power plant.

WHAT ARE THE ECONOMIC BENEFITS OF GASIFICATION?

Gasification has a number of significant economic benefits. It converts low-value feedstocks to high-value products, thereby increasing the use of available energy in the feedstocks while reducing disposal costs. If coal-based power plants are required to capture and sequester CO_2, gasification projects are expected to have a cost advantage over conventional coal combustion technologies.

WHAT IS THE GASIFICATION MARKET OUTLOOK?

World gasification capacity is projected to grow by more than 70% by 2015. More than 80% of the growth will occur in Asia, with China expected to achieve the most rapid expansion in gasification worldwide. Despite high construction costs and uncertainty about U.S. government policies, incentives, and regulations, gasification is expected to grow in the United States due to high and rising oil and natural gas prices, more stringent environmental regulations, and a growing consensus that CO_2 management will be required for electric power generation and manufacturing plants.

WHAT IS GASIFICATION?

Gasification is a manufacturing process that converts carbon-containing materials, such as coal, petcoke, biomass, or various wastes to a syngas which can then be used to produce electric power, valuable products, such as chemicals, fertilizers, substitute natural gas, hydrogen, steam, and transportation fuels.

Gasification is not Combustion

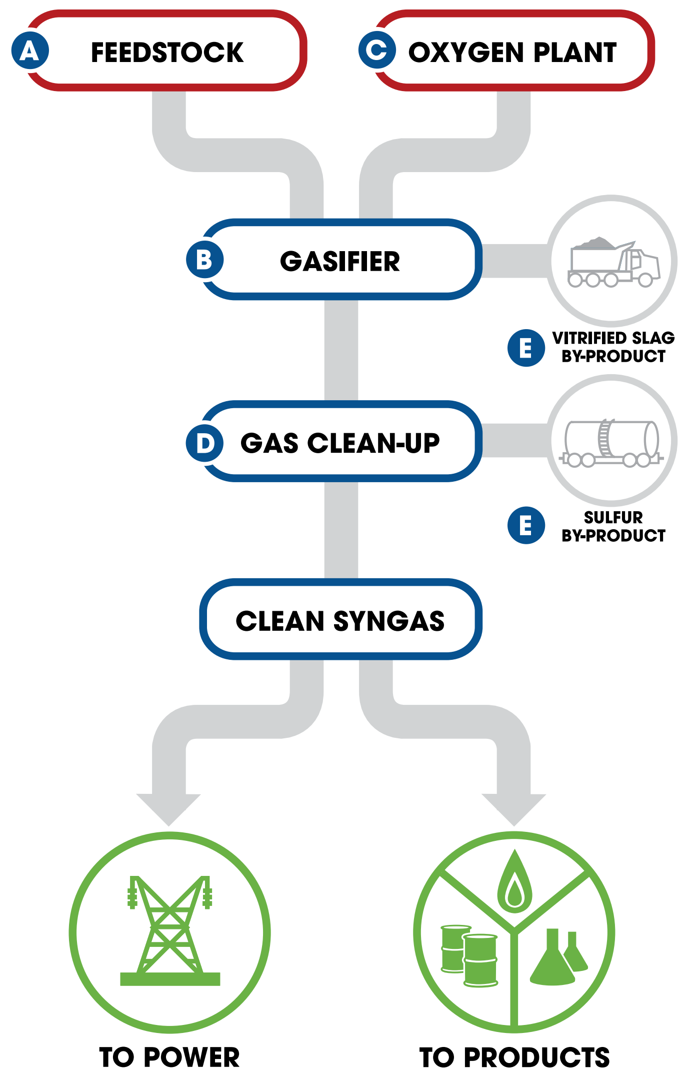
Gasification is a partial oxidation (reaction) process which produces syngas comprised primarily of hydrogen (H_2) and carbon monoxide (CO). It is not a *complete* oxidation (combustion) process, which produces primarily thermal energy (heat) and solid waste, criteria air pollutants (NO_x and SO_2), and carbon dioxide (CO_2).

GASIFICATION COMPARED TO COMBUSTION OF COAL

CONSTITUENTS OF COAL	GASIFICATION	COMBUSTION
CARBON	CO	CO_2
HYDROGEN	H_2	H_2O
NITROGEN	N_2	NO_x
SULFUR	H_2S	SO_2
OXYGEN	—	O_2

HOW DOES GASIFICATION WORK?

THE GASIFICATION PROCESS



A FEEDSTOCK

Gasification enables the capture — in an environmentally beneficial manner — of the remaining "value" present in a variety of low-grade hydrocarbon materials ("feedstocks") that would otherwise have minimal or even negative economic value.

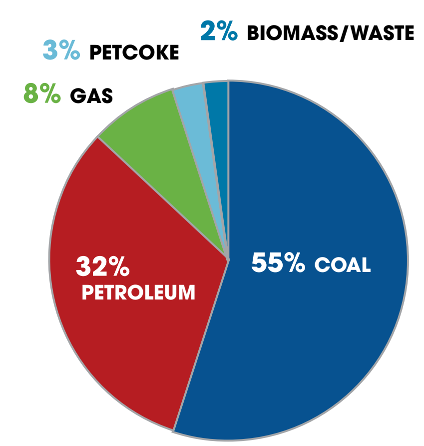
Gasifiers can be designed to run on a single material or a blend of feedstocks:

SOLIDS: All types of coal and petroleum coke (a low value byproduct of refining) and biomass, such as wood waste, agricultural waste, and household waste.

LIQUIDS: Liquid refinery residuals (including asphalts, bitumen, and other oil sands residues) and liquid wastes from chemical plants and refineries.

GAS: Natural gas or refinery/chemical off-gas.

GLOBAL SYNGAS OUTPUT BY FEEDSTOCK



B GASIFIER

The core of the gasification system is the gasifier, a pressurized vessel where the feed material reacts with oxygen (or air) and steam at high temperatures. There are several basic gasifier designs, distinguished by the use of wet or dry feed, the use of air or oxygen, the reactor's flow direction (up-flow, down-flow, or circulating), and the gas cooling process. Currently, gasifiers are capable of handling up to 3,000 tons/day of feedstock throughput and this will increase in the near future.

After being ground into very small particles — or fed directly (if a gas or liquid) — the feedstock is injected into the gasifier, along with a controlled amount of air or oxygen and steam. Temperatures in a gasifier range from 1,400-2,800 degrees Fahrenheit. The heat and pressure inside the gasifier break apart the chemical bonds of the feedstock, forming syngas.

The syngas consists primarily of hydrogen and carbon monoxide and, depending upon the specific gasification technology, smaller quantities of methane, carbon dioxide, hydrogen sulfide, and water vapor. Syngas can be combusted to produce electric power and steam or used as a building block for a variety of chemicals and fuels. Syngas generally has a heating value of 250-300 Btu/scf, compared to natural gas at approximately 1,000 BTU/scf.

Typically, 70–85% of the carbon in the feedstock is converted into the syngas. The ratio of carbon monoxide to hydrogen depends in part upon the hydrogen and carbon content of the feedstock and the type of gasifier used.

C OXYGEN PLANT

Most gasification systems use almost pure oxygen (as opposed to air) to help facilitate the reaction in the gasifier. This oxygen (95–99% purity) is generated in a plant using proven cryogenic technology. The oxygen is then fed into the gasifier through separate co-feed ports in the feed injector.

D GAS CLEAN-UP

The raw syngas produced in the gasifier contains trace levels of impurities that must be removed prior to its ultimate use. After the gas is cooled, the trace minerals, particulates, sulfur, mercury, and unconverted carbon are removed to very low levels using commercially proven cleaning processes common to the chemical and refining industries.

For feeds (such as coal) containing mercury, more than 95% of the mercury can be removed from the syngas using relatively small and commercially available activated carbon beds.

CO_2

Carbon dioxide (CO_2) can also be removed at the gas cleanup stage using a number of commercial technologies. In fact, CO_2 is routinely removed with a commercially proven process in ammonia and hydrogen manufacturing plants. Ammonia plants already capture approximately 90% of the CO_2 and methanol plants capture approximately 70%. *(This removal process is discussed more fully at page 17.)*

E BY-PRODUCTS

Most solid and liquid feed gasifiers produce a glass-like byproduct called slag, which is non-hazardous and can be used in roadbed construction or in roofing materials. Also, in most gasification plants, more than 99% of the sulfur is removed and recovered either as elemental sulfur or sulfuric acid.

WHICH INDUSTRIES USE GASIFICATION?

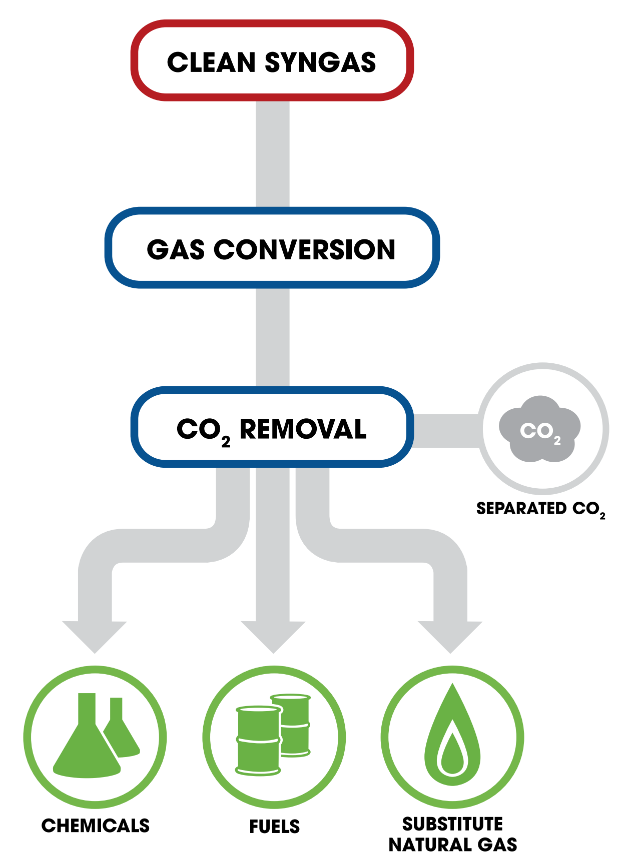
Gasification has been used in the chemical, refining, and fertilizer industries for more than 50 years and by the electric power industry for more than 35 years. Currently, there are more than 140 gasification plants — with more than 420 gasifiers — operating worldwide. Nineteen of those gasification plants are located in the United States.

The use of gasification is expanding. For example, there are several gasification projects under development to provide steam and hydrogen for synthetic crude upgrading in the oil sands industry in Canada. In addition, the paper industry is exploring how gasification can be used to make their operations more efficient and reduce waste streams.

Gasification Applications and Products

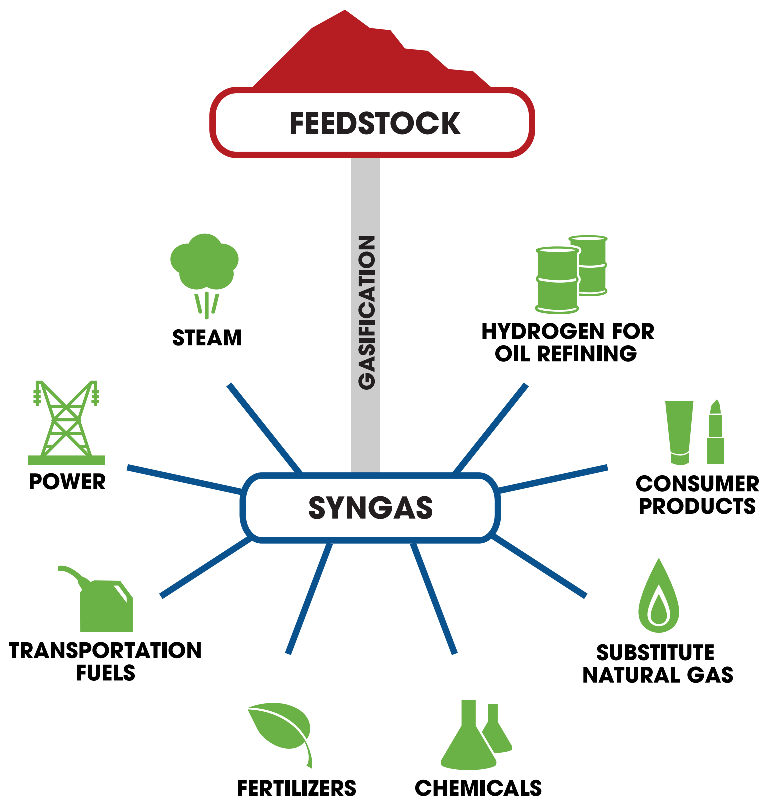
Hydrogen and carbon monoxide, the major components of syngas, are the basic building blocks of a number of other products, such as chemicals and fertilizers. In addition, a gasification plant can be designed to produce more than one

GASIFICATION FOR PRODUCTS



product at a time (co-production or "polygeneration"), such as the production of electricity, steam, and chemicals (e.g., methanol or ammonia). This polygeneration flexibility allows a facility to increase its efficiency and improve the economics of its operations.

GASIFICATION PRODUCTS



CHEMICALS AND FERTILIZERS

Modern gasification has been used in the chemical industry since the 1950s. Typically, the chemical industry uses gasification to produce methanol as well as chemicals — such as ammonia and urea — which form the foundation of nitrogen-based fertilizers. The majority of the operating gasification plants worldwide are designed to produce chemicals and fertilizers. And, as natural gas and oil prices continue to increase, the chemical industry is developing additional coal gasification plants to generate these basic chemical building blocks.

Eastman Chemical Company helped advance the use of coal gasification technology for chemicals production. Eastman's coal-to-chemicals plant in Kingsport, Tennessee, converts Appalachian coals to methanol and acetyl chemicals. The plant began operating in 1983 and has gasified approximately 10 million tons of coal with a 98–99% on-stream availability rate.

HYDROGEN FOR OIL REFINING

Hydrogen, one of the two major components of syngas, is used to strip impurities from gasoline, diesel fuel, and jet fuel, thereby producing the clean fuels required by state and federal clean air regulations. Hydrogen is also used to upgrade heavy crude oil. Historically, refineries have utilized natural gas to produce this hydrogen. Now, with the increasing price of natural gas, refineries are looking to alternative feedstocks to produce the needed hydrogen. Refineries can gasify low-value residuals, such as petroleum coke, asphalts, tars, and some oily wastes from the refining process to generate both the required hydrogen and the power and steam needed to run the refinery.

TRANSPORTATION FUELS

Gasification is the foundation for converting coal and other solid feedstocks and natural gas into transportation fuels, such as gasoline, ultra-clean diesel fuel, jet fuel, naphtha, and synthetic oils. Two basic paths are employed in converting coal to motor fuels via gasification. In the first, the syngas undergoes an additional process, the Fischer-Tropsch (FT) reaction, to convert it to a liquid petroleum product. The FT process, with coal as a feedstock, was invented in the 1920s, used by Germany during World War II, and has been utilized in South Africa for decades. Today, it is also used in Malaysia and the Middle East with natural gas as the feedstock.

In the second process, so-called Methanol to Gasoline (MTG), the syngas is first converted to methanol (a commercially used process) and the methanol is converted to gasoline by reacting it over a bed of catalysts. A commercial MTG plant successfully operated in the 1980s and early 1990s in New Zealand and projects are under development in China and the U.S.

TRANSPORTATION FUELS FROM OIL SANDS

The "oil sands" in Alberta, Canada are estimated to contain as much recoverable oil (in the form of bitumen) as the vast oil fields in Saudi Arabia. However, to convert this raw material to saleable products requires mining the oil sands and refining the resulting bitumen to transportation fuels. The mining process requires massive amounts of steam to separate the bitumen from the sands and the refining process demands large quantities of hydrogen to upgrade the "crude oil" to finished products. (Residuals from the upgrading process include petcoke, deasphalted bottoms, vacuum residuals, and asphalt/asphaltenes — all of which contain unused energy.)

Traditionally, oil sand operators have utilized natural gas to produce the steam and hydrogen needed for the mining, upgrading, and refining processes. However, a number of operators have plans to gasify bitumen residues to supply the necessary steam and hydrogen. Not only will gasification displace expensive natural gas as a feedstock, it will enable the extraction of usable energy from what is otherwise a waste product (the petcoke). In addition, black water from the mining and refining processes can be recycled to the gasifiers using a wet feed system, reducing fresh water usage and waste water management costs. (This is not inconsequential since traditional oil sand operations consume large volumes of water.)

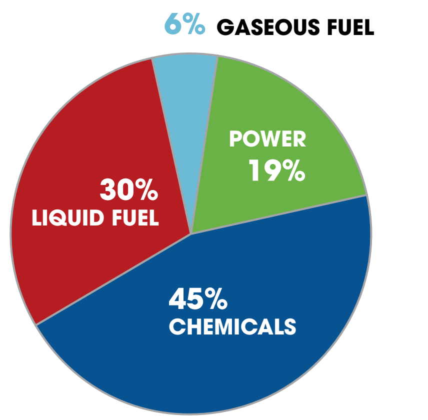
SUBSTITUTE NATURAL GAS

Gasification can also be used to create substitute natural gas (SNG) from coal. Using a "methanation" reaction, the coal-based syngas — chiefly carbon monoxide (CO) and hydrogen (H_2) — can be profitably converted to methane (CH_4). Nearly chemically identical to conventional natural gas, the resulting SNG can be used to generate electricity, produce chemicals/fertilizers, or heat homes and businesses. SNG will enhance domestic fuel security by displacing imported natural gas that is likely to be supplied in the form of Liquefied Natural Gas (LNG).

POWER GENERATION WITH GASIFICATION

As stated above, coal can be used as a feedstock to produce electricity from gasification. This particular coal-to-power technology allows the continued use of coal without the high level of air emissions associated with conventional coal-burning technologies. This occurs because in gasification power plants the pollutants in the syngas are removed before the syngas is combusted in the turbines. In contrast, conventional coal combustion technologies capture the pollutants after the exhaust gas has passed through the boiler or steam generator — generally using an expensive "bag house" and/or "scrubber."

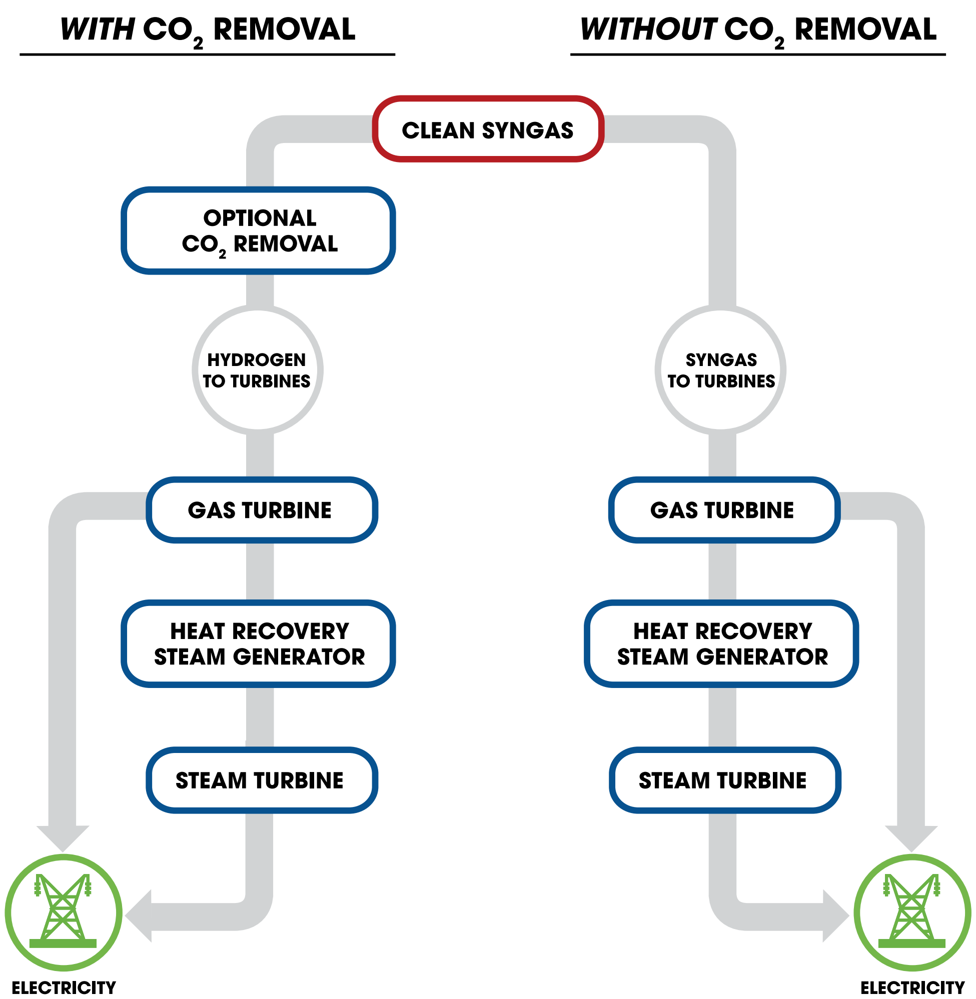
PRODUCT DISTRIBUTION OF 2007 WORLD GASIFICATION CAPACITY



IGCC Power Plants

An Integrated Gasification Combined Cycle (IGCC) power plant combines the gasification process described on pages 4–6, with a "combined cycle" power block (consisting of one or more gas turbines and a steam turbine). Clean syngas is combusted in high efficiency gas turbines to produce electricity. The excess heat from the gasification reaction is then captured, converted into steam, and sent to a steam turbine to produce additional electricity. The gas turbines can be operated on a backup fuel such as natural gas during periods of scheduled gasifier maintenance or can co-fire the backup fuel to compensate for any shortfall in syngas production.

GASIFICATION FOR POWER



GAS TURBINES

In IGCC — where power generation is the focus — the clean syngas is combusted (burned) in high efficiency gas turbines to generate electricity with very low emissions. The turbines used in these plants are derivatives of proven, natural gas combined-cycle turbines that have been specially adapted for use with syngas. For IGCC plants that include carbon capture, the gas turbines must be able to operate on syngas with higher levels of hydrogen. Although modern state-of-the-art gas turbines are commercially ready for this "higher hydrogen" syngas, work is on-going in the United States to develop the next generation of even more efficient gas turbines ready for carbon capture-based IGCC.

HEAT RECOVERY STEAM GENERATOR

Hot gas from each gas turbine in an IGCC plant will "exhaust" into a heat recovery steam generator (HRSG). The HRSG captures heat in the hot exhaust from the gas turbines and uses it to generate additional steam that is used to make more power in the steam turbine portion of the combined-cycle unit.

STEAM TURBINES

In most IGCC plant designs, steam recovered from the gasification process is superheated in the HRSG to increase overall efficiency output of the steam turbines, hence the name Integrated Gasification Combined Cycle. This IGCC combination, which includes a gasification plant, two types of turbine generators (gas and steam), and the HRSG is clean and efficient — producing NO_x levels less than 0.06lb per MMBtu (coal input basis) and combined cycle efficiencies exceeding 65% when process steam integrated from the gasification plant is included.

Another example of the "integrated" design in the fully integrated IGCC is the IGCC gas turbine, which can provide a portion of the compressed air to the oxygen plant. This reduces the capital cost of the compressors while also decreasing the amount of power required to operate the oxygen plant. Additionally, gas turbines use nitrogen from the oxygen plant to reduce combustion NO_x as well as increase power output.

Existing IGCC Power Plants

Fourteen gasification-based power plants are operating around the world with one more under construction. Total capacity for these fifteen plants will be 4.1 gigawatts of electricity. Numerous additional projects are planned.

WORLD GASIFICATION-BASED POWER GENERATING CAPACITY

PLANT NAME	LOCATION	YEAR START	OUTPUT (MW)	FEED
Nuon	Buggenum, Netherlands	1994	250	Coal/Biomass
Wabash	Terre Haute, IN, USA	1995	260	Coal/Petcoke
Tampa Electric	Polk County, FL, USA	1996	250	Coal/Petcoke
Vresova	Vresova, Czech Republic	1996	350	Coal/Petcoke
Schwarze Pumpe	Lausitz, Germany	1996	40	Coal/Biomass
Pernis Refinery	Rotterdam, Netherlands	1997	120	Visbreaker/Tar
Elcogas	Puertollano, Spain	1998	300	Coal/Petcoke
ISAB Energy	Sicily, Italy	2000	520	Asphalt
Sarlux	Sardinia, Italy	2001	545	Visbreaker/Tar
Chawan IGCC	Jurong Island, Singapore	2001	160	Tar
api Energia	Falconara, Italy	2002	280	Visbreaker/Tar
Valero	Delaware City, DE, USA	2003	160	Petcoke
Negishi IGCC	Negishi, Japan	2003	342	Asphalt
Eni Sannazzaro	Sannazzaro, Italy	2006	250	Oil Residues
Fujian Petrochemical	Quanzhou, China	2009	280	Oil Residues
		TOTAL CAPACITY	4,107	

Source: World Gasification Database; Gasification Technologies Council

In the U.S., two coal-based IGCC's have been in operation for more than a decade. The 262 MW Wabash River Coal Gasification Repowering Project (Wabash) in Indiana began commercial operation in November 1995 and helped pioneer the use of coal gasification for power in the United States. Since 1995, this facility has gasified more than 1.7 million tons of bituminous coal and more than 2.0 million tons of petcoke.

Tampa Electric Company also helped pioneer the use of coal gasification technology for power generation in the United States. Tampa's 250 MW Polk Power Station near Lakeland, Florida, began operating in 1996 and serves 75,000 households. The Polk plant uses high sulfur Illinois and other coals, but also blends Powder River Basin coal and petcoke in order to reduce fuel costs. The Polk Power station markets the slag from the gasifier for use in the manufacture of roofing and concrete blocks. Sulfuric acid, another by-product, goes into fertilizer production.

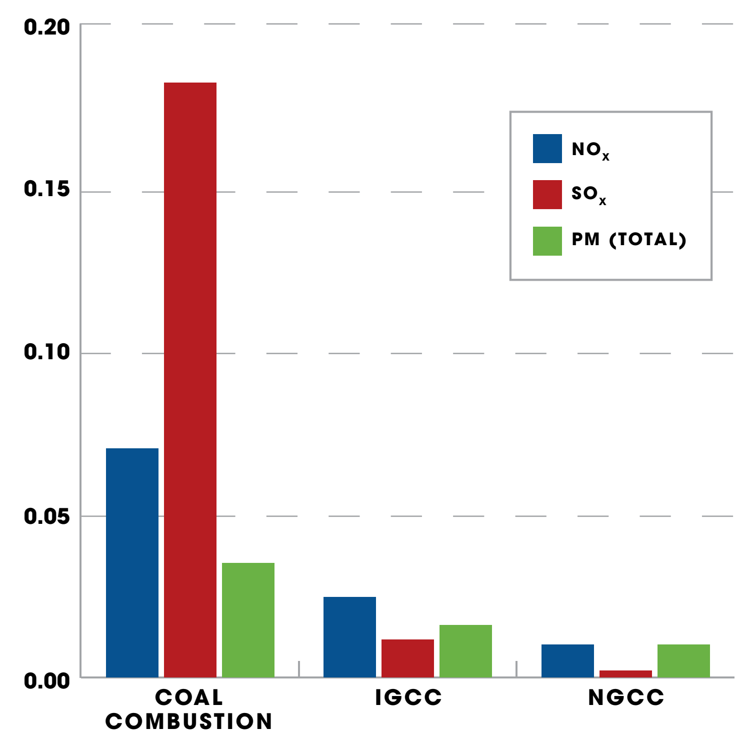
WHAT ARE THE ENVIRONMENTAL BENEFITS OF GASIFICATION?

Besides fuel and product flexibility, gasification-based systems offer significant environmental advantages over competing technologies, particularly coal-to-electricity combustion systems. This advantage occurs because the net volume of syngas being treated pre-combustion in an IGCC power plant is 1/100 (or less) of the volume of post-combustion exhaust gas that must be cleansed in a conventional coal-fired plant.

AIR EMISSIONS

Gasification can achieve greater air emission reductions at lower cost than other coal consumption technologies, such as supercritical pulverized coal. Coal IGCC offers the lowest emissions of sulfur dioxide (SO_x) nitrogen oxides (NO_x) and particulate matter (PM) of any coal-based power production technology. In fact, a coal IGCC plant is able to achieve low air emissions rates that approach those of a natural gas combined cycle (NGCC) power plant. In addition, mercury emissions can be removed from an IGCC plant at one-tenth the cost of removal for a coal combustion plant. Technology exists today to remove more than 95% of the mercury from a gasification-based plant.

AIR EMISSIONS FROM POWER GENERATION
(POUNDS PER MILLION BTU'S OF FUEL/FEEDSTOCK INPUT)



Sources: For IGCC and Coal Combustion: IL Dept. of Environmental Protection air permits for projects under development; For NGCC – GE Energy

SOLIDS GENERATION

During gasification, virtually all of the carbon in the feedstock is converted to syngas.[1] The mineral material in the feedstock separates from the gaseous products, and the ash and other inert materials melt and fall to the bottom of the gasifier as a non-leachable, glass-like solid or other marketable material. This material can be used for many construction and building applications. In addition, more than 99% of the sulfur can be removed using commercially proven technologies and converted into marketable elemental sulfur or sulfuric acid. *(See chart on page 17)*

WATER USAGE

Gasification uses approximately 14–24% less water to produce electric power from coal compared to other coal-based technologies, and water losses during operation are about 32–36% less than other coal-based technologies.[2] This is a major issue in many countries — including the United States — where water supplies have already reached critical levels in certain regions.

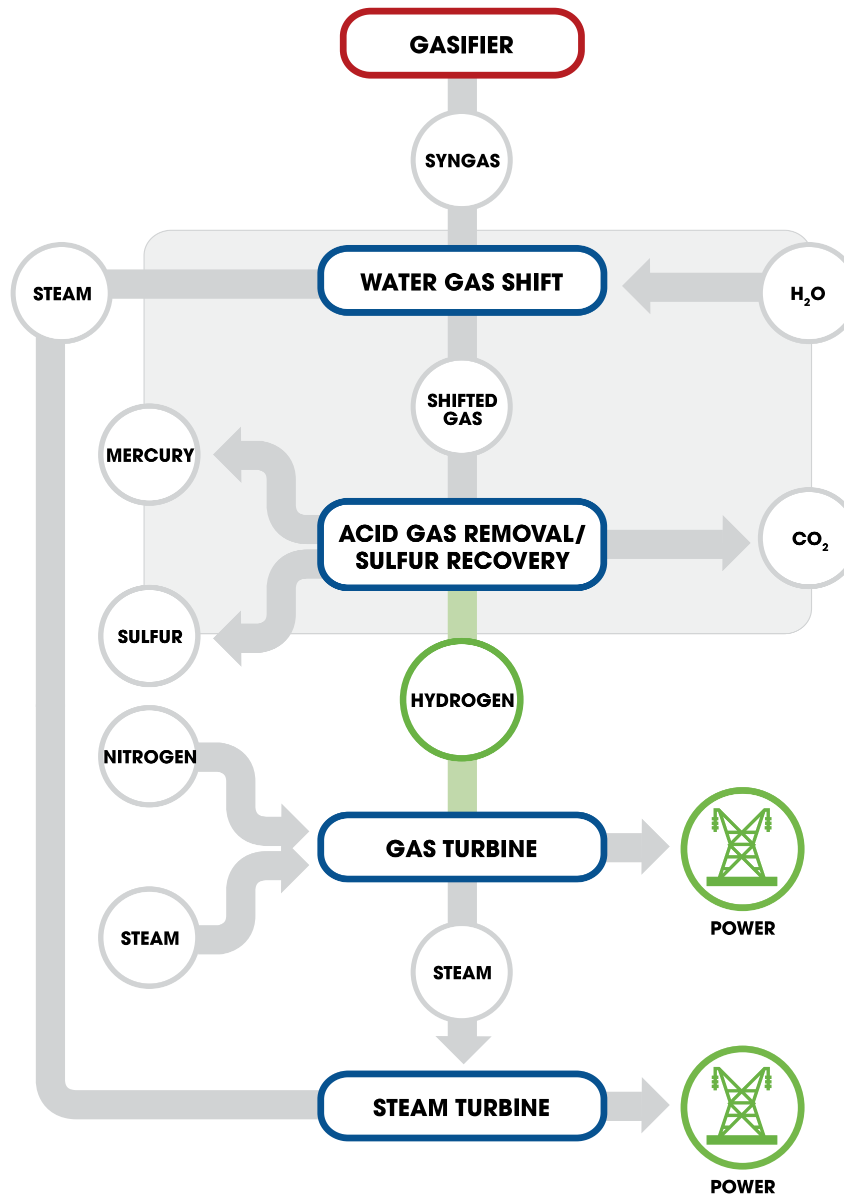
CARBON DIOXIDE

In a gasification system, CO_2 can be captured using commercially available technologies before it would otherwise be vented to the atmosphere. One, called the water-gas shift reaction, is illustrated on the following page.

1/ Higman, Christopher and van der Burgt, Martin, Gasification, Gulf Professional Publishing, 2003. P.100

2/ Final Report Environmental Footprints and Costs of Coal-Based Integrated Gasification Combined Cycle and Pulverized Coal Technologies; Environmental Protection Agency, July 2006. P. 3-36

CO_2 REMOVAL FLOW



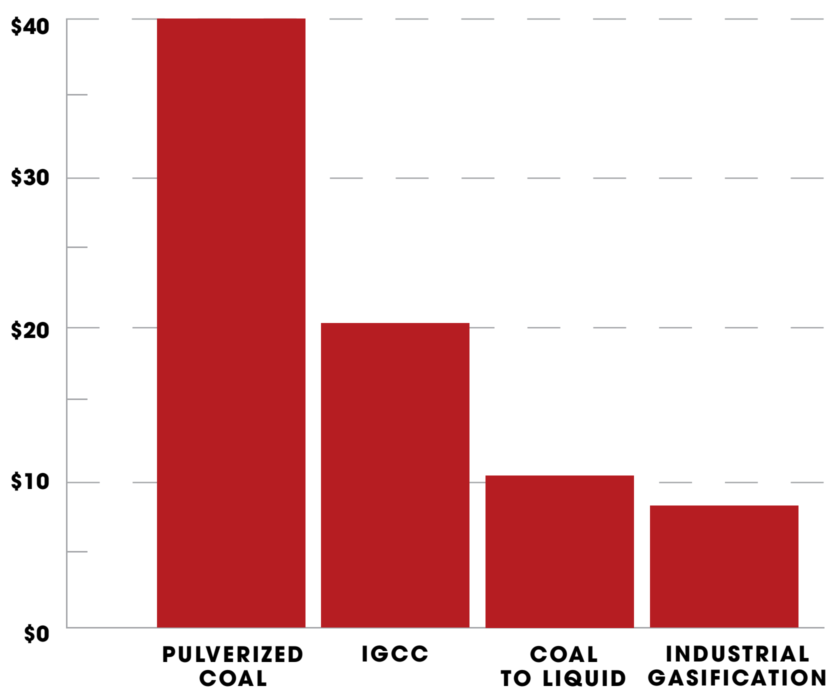
Converting the CO to CO_2 prior to combustion is more economical than removing CO_2 after combustion, effectively "de-carbonizing", or at least, reducing the carbon in the syngas.

Gasification plants manufacturing ammonia, hydrogen, fuels, or chemical products routinely capture CO_2 as part of the manufacturing process. The Dakota Gasification plant in Beulah, North Dakota, captures the CO_2 while making substitute natural gas (SNG). Since 2000, this plant has sent captured CO_2 via pipeline to EnCana's Weyburn oil fields in Saskatchewan, Canada, where it is used for enhanced oil recovery. More than five million tons of CO_2 have been sequestered.

According to the Environmental Protection Agency, the higher thermodynamic efficiency of the IGCC cycle minimizes CO_2 emissions relative to other technologies.[3] IGCC plants offer today's least-cost alternative for capturing CO_2 from a coal-based power plant. In addition, IGCC will experience less of an energy penalty than other technologies if carbon capture is required. While CO_2 capture and sequestration will increase the cost of all forms of power generation, an IGCC plant can capture and compress CO_2 at one half the cost of a traditional pulverized coal plant. Other gasification based options, including production of motor fuels, chemicals, fertilizers or hydrogen, to name a few, have even lower carbon capture and compression costs. This will provide a significant economic and environmental benefit in a carbon constrained world.

CARBON CAPTURE & COMPRESSION COSTS*

(DOLLARS PER METRIC TON)



*Mark Costa 2007 GTC Presentation
Source: MIT and Eastman Chemical Company

3/ Supra, Note 2. P. 3-28

WHAT ARE THE ECONOMIC BENEFITS OF GASIFICATION?

Gasification can compete effectively in high-cost energy environments. While a gasification plant is capital intensive (like any manufacturing unit), its operating costs are potentially lower than many other manufacturing processes or coal combustion plants because a gasification plant can use low-cost feedstocks, such as petcoke or high sulfur coal. Continued research, development, and demonstration investment efforts continue to decrease costs.

Gasification has a number of significant economic benefits. It converts low-value feedstocks to high-value products, thereby increasing the use of available energy in the feedstocks while reducing disposal costs. The ability to produce a number of high-value products at the same time (polygeneration) helps a facility offset its capital and operating costs. In addition, the principal gasification byproducts (sulfur and slag) are readily marketable.

Gasification offers wide fuel flexibility. A gasification plant can vary the mix of the solid feedstocks or run on natural gas or liquid feedstocks when desirable. This technology enables an industrial facility to replace its high-priced natural gas feed with lower priced feedstocks, such as coal or petcoke — thus reducing its operating costs.

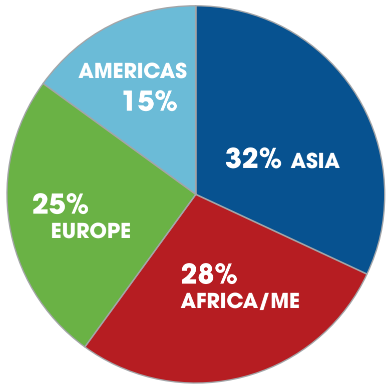
For example, a refinery using gasification to manufacture hydrogen and steam can replace its natural gas feedstock with lower-value materials, such as petcoke. The ability to use lower value fuels enables a refinery to reduce both its fuel and disposal costs while producing the large quantities of hydrogen that are needed for cleaner transportation fuels.

In addition, gasification units require less pollution control equipment because they generate fewer emissions, further reducing the plant's operating costs.

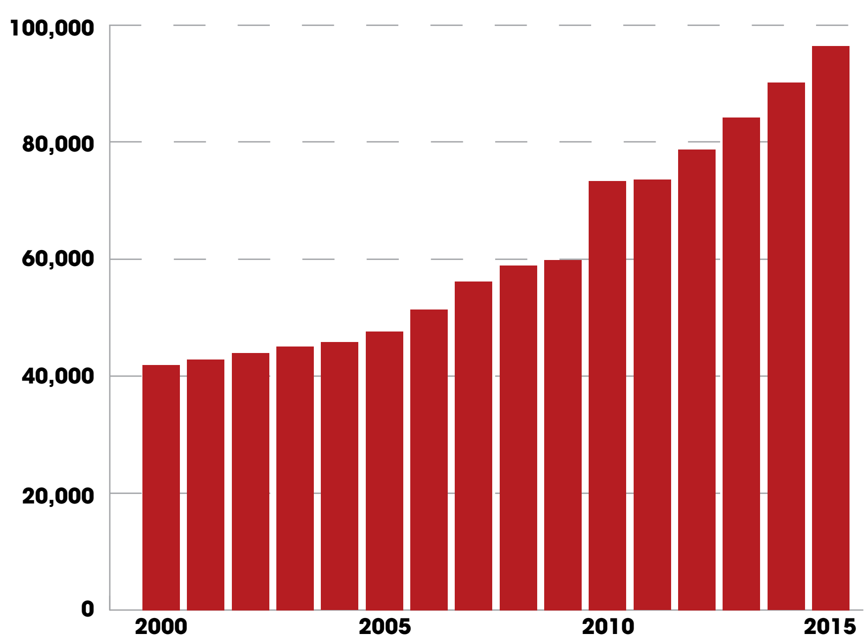
WHAT IS THE GASIFICATION MARKET OUTLOOK?

Worldwide gasification capacity is projected to grow 70% by 2015, with 81% of the growth occurring in Asia. The prime movers behind this expected growth are the chemical, fertilizer, and coal-to-liquids industries in China, oil sands in Canada, polygeneration (hydrogen and power or chemicals) in the United States, and refining in Europe. China is expected to achieve the most rapid growth in gasification worldwide. Since 2004, 29 new gasification plants have been licensed or built in China. By contrast, no new gasification plants have started up in the United States since 2002.

GLOBAL SYNGAS CAPACITY BY REGION



WORLD SYNGAS CAPACITY GROWTH
(MEGAWATTS THERMAL EQUIVALENT)



Source: Gasification Technologies Council

EXISTING GASIFICATION PLANTS IN THE U.S.

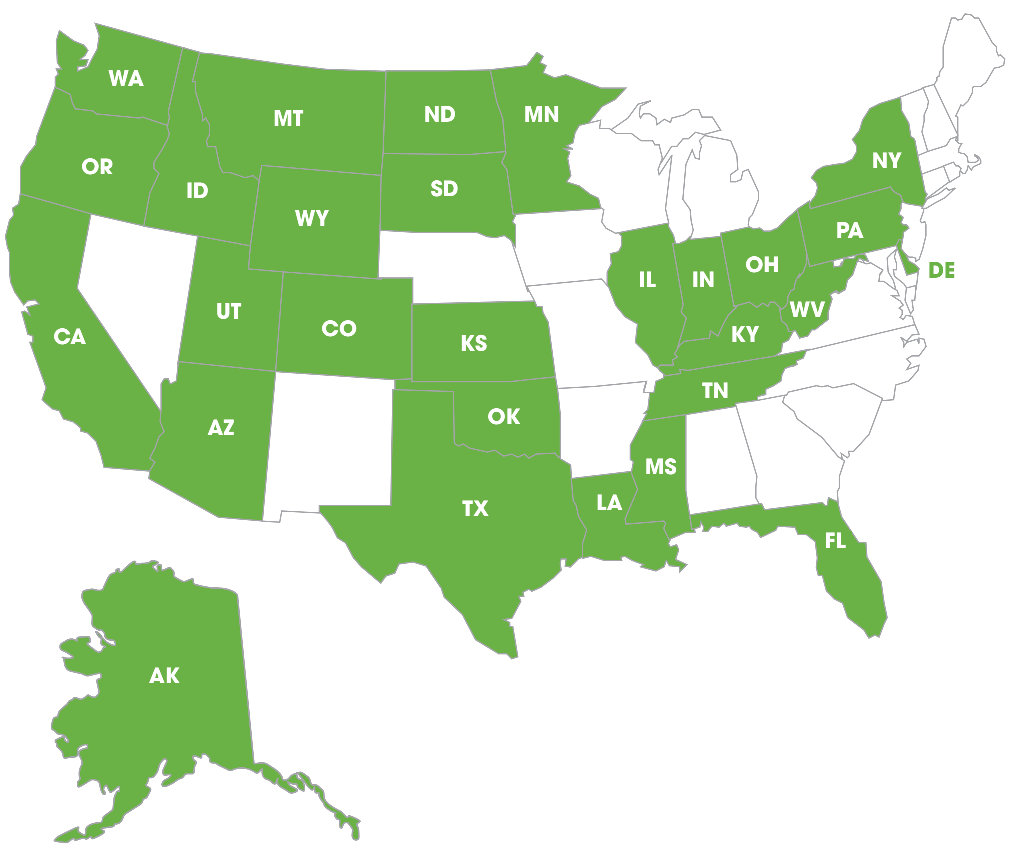
PLANT NAME	LOCATION	YEAR	MAIN PRODUCT	FEED CLASS	SYNGAS OUTPUT*
Houston Oxochemicals Plant	Houston, TX	1977	Chemicals	Gas	287
Baton Rouge Oxochemicals Plant	Baton Rouge, LA	1978	Chemicals	Petroleum	78
LaPorte Syngas Plant	Deer Park, TX	1979	Chemicals	Gas	656
Hoechst Oxochemicals Plant	Bay City, TX	1979	Chemicals	Petroleum	68
Kingsport Integrated Coal Gasification Facility	Kingsport, TN	1983	Chemicals	Coal	219
Sunoco Oxochemicals Plant	Texas	1983	Chemicals	Gas	55
Texas City Dow Syngas Plant	Texas City, TX	1983	Chemicals	Gas	114
Great Plains Synfuels Plant	Bismarck, ND	1984	Gaseous fuels	Coal	1900
Convent H_2 Plant	Convent, LA	1984	Chemicals	Petroleum	257
Wabash River Energy Ltd.	West Terre Haute, IN	1995	Power	Petcoke	591
Taft Syngas Plant	Taft, LA	1995	Chemicals	Gas	59
LaPorte Syngas Plant	LaPorte, TX	1996	Chemicals	Gas	253
Texas City Praxair Syngas Plant	Texas City, TX	1996	Chemicals	Gas	278
Polk County IGCC Project	Mulberry, FL	1996	Power	Coal	451
Oxochemicals Plant	Texas	1998	Chemicals	Gas	48
Coffeyville Syngas Plant	Coffeyville, KS	2000	Chemicals	Petcoke	293
Baytown Syngas Plant	Baytown, TX	2000	Gaseous fuels	Petroleum	347
Delaware Clean Energy Cogeneration Project	Delaware City, DE	2002	Power	Petcoke	520
Longview Gasification Plant	Longview, TX	2002	Chemicals	Gas	213

**Syngas output in megawatts thermal*
Source: World Gasification Database; Gasification Technologies Council

The gasification industry in the United States faces a number of challenges, including rising construction costs and uncertainty about policy incentives and regulations. Despite these challenges, U.S. gasification capacity is expected to grow significantly.

A number of factors will contribute to a growing interest in gasification, including volatile oil and natural gas prices, more stringent environmental regulations, and a growing consensus that CO_2 management should be required in power generation and energy production.

STATES WHERE GASIFICATION PLANTS HAVE BEEN PROPOSED

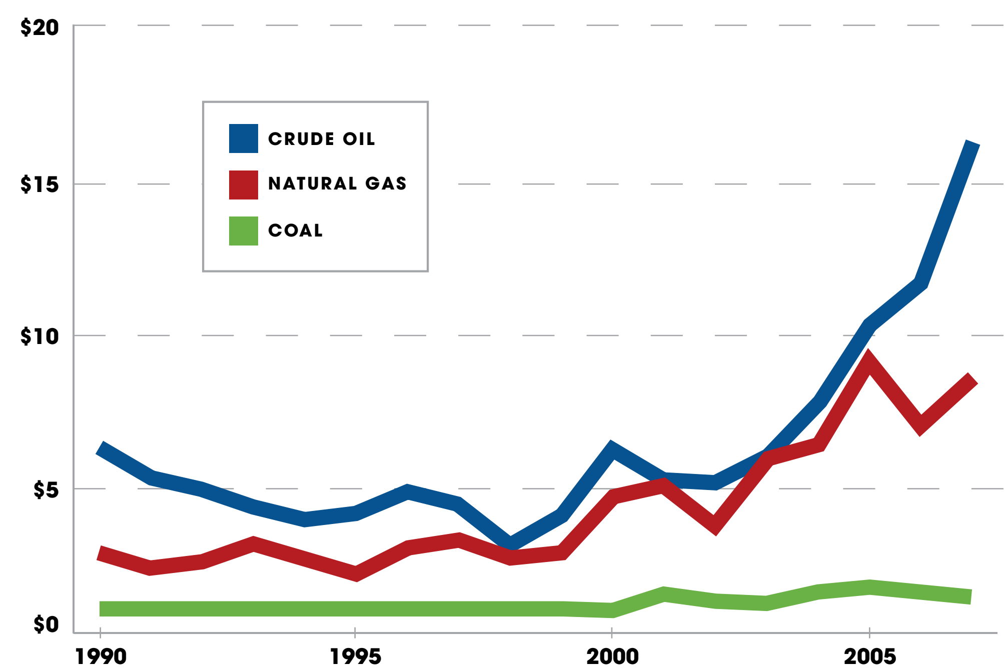


ENERGY PRICES

America is at a critical juncture in meeting its electric generating needs. Natural gas prices are volatile and while new natural gas supplies are being developed, those supplies are generally located outside the country. In addition, there is increasing concern about the need to diversify U.S. fuel supplies. Gasification is a technology that can help address some of these energy security concerns. Gasification can generate electricity and produce substitute natural gas and transportation fuels using major domestic resources such as coal or petroleum coke, thus reducing U.S. dependence on both foreign oil and foreign natural gas.

U.S. ENERGY PRICES

(DOLLARS PER MILLION BTU'S)



Source: U.S. Energy Information Administration

BIOPROCESSING

In addition to using the traditional feedstocks of coal and petroleum coke, gasifiers can utilize biomass, such as yard and crop waste, "energy crops", such as switch grass, and waste and residual pulp/paper plant materials as feed. Municipalities as well as the paper and agricultural industries are looking for ways to reduce the disposal costs associated with these wastes and for technologies to produce electricity and other valuable products from these waste materials. While still in its infancy, biomass gasification shows a great deal of promise.

A LINK TO THE FUTURE

Gasification is a "link" technology to a hydrogen economy. Because gasification converts feedstocks such as coal directly into hydrogen, it can become a competitive route to producing the large quantifies of hydrogen that will be needed for fuel cells and cleaner fuels. By contrast, other technologies must first create the electricity needed to separate the hydrogen from water, using electricity or expensive natural gas.

CONCLUSIONS

Gasification is the cleanest, most flexible and reliable way of using fossil-fuels. It can convert low-value residuals into high-value products, such as chemicals and fertilizers, substitute natural gas, transportation fuels, electric power, steam, and hydrogen.

Gasification provides the least-cost alternative for capturing CO_2 when generating power, permitting the United States to use its abundant coal reserves to generate needed electricity in a carbon-constrained world.

Gasification offers opportunities to use domestic resources to displace high-cost imported petroleum and natural gas from politically unstable regions of the world.

Gasification provides increased domestic investment and jobs in industries that have been in decline because of high energy costs.

And, finally,
Gasification offers a path to new energy development and use consistent with robust environmental stewardship.

Gasification is redefining clean energy.