U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory

# CURRENT INDUSTRY PERSPECTIVE

# Gasification

## ROBUST GROWTH FORECAST

## World Survey Results

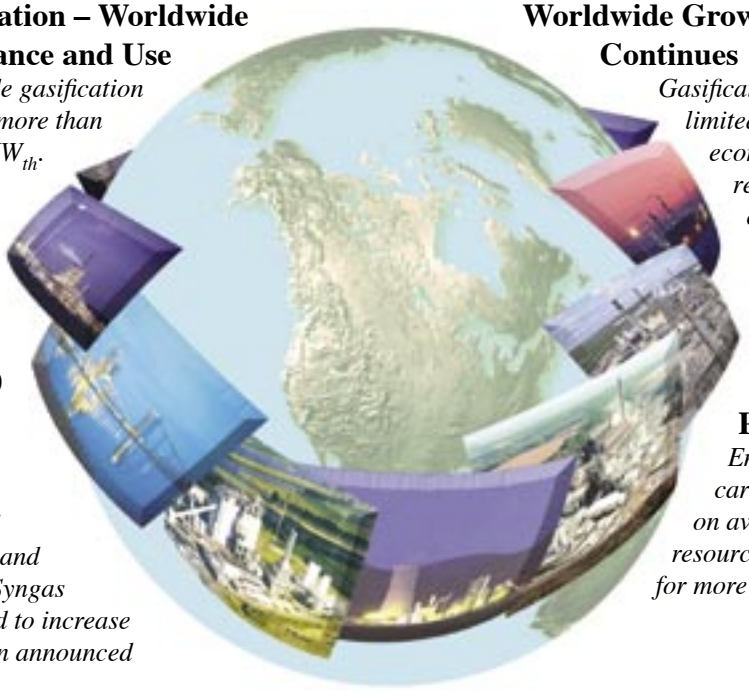
2004

# *A Current Perspective On the Gasification Industry*

## ROBUST GROWTH FORECAST

**Pre-1999**
**Gasification – Worldwide Acceptance and Use**
*Worldwide gasification capacity more than 42,000 $MW_{th}$.*

**Actual 2000-2004**
**Worldwide Growth Continues**
*Gasification growth limited by uncertain economic conditions and readily available low-cost natural gas. Syngas capacity growth continues to over 45,000 $MW_{th}$.*



**Planned 2005-2010**
**A Robust Industry Rebounds**
*Gasification growth encouraged by projected economic improvements and oil/gas price increases. Syngas capacity growth expected to increase by 25,000 $MW_{th}$ based on announced construction plans.*

**Post-2010 and Beyond**
*Environmental drivers such as carbon capture and constraints on availability/cost of oil and gas resources should create opportunities for more gasification-based projects.*

# *Gasification Plants Around the World*

The United States Department of Energy (DOE) National Energy Technology Laboratory (NETL) commissioned the first world gasification survey in 1999. The purpose of the latest survey is to update that prior effort and to provide credible, timely information regarding the state of the world gasification industry today. Conducted in 2004, the survey provides a profile of operating gasification plants, construction plans through 2010, and information on trends and drivers affecting the growth of the industry.

# SUMMARY

*Gasification continues its expansion and upward growth trend.*

The United States Department of Energy (DOE) sponsored the 2004 World Gasification Survey in order to accurately describe the world gasification industry as it exists today, to identify planned capacity additions, and to keep the gasification community apprised of current data and trends. This 2004 survey was completed by Childress Associates in collaboration with members of the Gasification Technologies Council (GTC) and follows the initial 1999 worldwide survey and 2001 update.

## World Gasification in 2004

The 2004 World Gasification Survey shows that existing world gasification capacity has grown to 45,001 megawatts thermal ($MW_{th}$) of syngas output at 117 operating plants with a total of 385 gasifiers. Major aspects of the global syngas capacity are categorized below:

- Regional distribution: The existing gasification plants are operating in 24 countries, which the database groups into five regions. The Africa/Middle East region, with 34% of the total capacity, is now the leading region in the world for syngas production.
- Feedstock distribution: Coal remains the predominant feedstock, accounting for 49% of syngas capacity generated from all feedstocks. Petroleum provides 37%, with the remaining 14% of gasifier feedstocks coming from natural gas, petcoke, and biomass/wastes.
- Product distribution: The primary product of operating gasification plants is synthesis gas (or syngas) from which other marketable products are generated, including chemicals (37%), Fischer Tropsch liquids (36%), power (19%), and gaseous fuels (8%).
- Technology distribution: Three commercially-proven technologies currently command 94% of the 2004 world market: Sasol Lurgi technology represents 41% of the gasification operating production capacity, GE Energy (formerly Texaco) represents 34% of reported capacity, and Shell technology represents 19%.

## Planned Growth During 2005 to 2010

An additional 38 plants with 66 gasifiers have been announced and are forecast to become operational between 2005 and 2010, according to the 2004 survey. The additional capacity from these new plants is 25,282 $MW_{th}$, an expected increase of 56%. Worldwide capacity by 2010 is projected at 70,283 $MW_{th}$ of syngas output from 155 plants and 451 gasifiers.

- Regional distribution: The Africa/Middle East region will lead the world's regional growth with 43% of planned capacity growth from 2005 to 2010, all from a single gas-to-liquids (GTL) project in Qatar that will produce liquid fuels from natural gas. The Asia/Australia region has planned projects that comprise 37% of the total planned growth, with China leading in this region. By contrast, plans for new gasification plants slowed in North America due to factors such as the economy and natural gas prices.
- Feedstock distribution: Coal is the feedstock of choice for new gasification projects, identified for 29 of the 38 new plants (largely on the strength of the 24 chemical plants to be built in China). However, natural gas will be used in the largest single project from 2005 to 2010 at the nearly 11,000 $MW_{th}$ gas-to-liquids gasification plant in Qatar.
- Product distribution: Chemicals will be the leading gasification product, generated at 24 of the 38 plants, with the GTL plant in Qatar producing 140,000 barrels per day of distillate liquids. Power will be produced at seven of the remaining plants.
- Technology distribution: Survey results predict that Shell gasification technology will be used at 24 of the 38 plants built between 2005 and 2010. On this basis, Shell will then account for 43% of the market syngas capacity by

2010 (largely on the basis of the natural gas conversion facility to be built in Qatar), compared to its 19% market share in 2004. By contrast, Sasol Lurgi (dry ash) technology is projected to slip from a 41% market share in 2004 to 27% in 2010. GE Energy gasifiers are planned at six new plants and ConocoPhillips E-Gas technologies at another six plants.

## Changes and Drivers

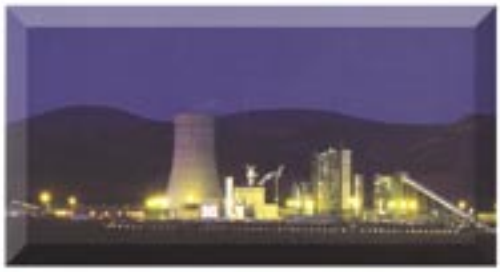
The 2004 survey results show a 5% increase in syngas output since 1999, mostly due to increased growth in China, where plants were primarily built to convert coal or petroleum waste to chemicals and fertilizers. This trend is expected to continue. In contrast, growth in North America over the past five years was initially hampered by a sluggish economy and low natural gas prices. Since natural gas prices are rising and costs are expected to grow, gasification plant construction announcements are increasing. Moreover, future growth may be spurred by environmental waste gasification to avoid more costly disposal and by increasing public demand for clean energy.

## Afterword

Since the completion of the 2004 survey and the subsequent evaluation of the data, additional information regarding future gasification plants has become available and is provided in the "Afterword" section. Such information is particularly applicable to U.S. interests in gasification. A list of 27 potential coal gasification projects in early planning stages in the U.S. is provided along with some discussion of legislative policies and incentives that have recently been enacted and are likely to make the construction of more gasification plants increasingly attractive.

The 262 megawatt Wabash River Repowering integrated gasification combined-cycle (IGCC) plant in Terre Haute, Indiana has been operating since 1995, initially as part of the DOE Clean Coal Technology Program. Using E-Gas technology, the plant has operated more than 15,000 hours, using both coal and petroleum coke feed during its demonstration stage. It is now operating commercially.

The Tampa Electric Polk Power Station, operating since 1996, is the second commercial U.S. IGCC plant built as part of the DOE Clean Coal Technology Program. It has been in operation commercially since 2001, after completion of its demonstration period under the DOE program. The Polk station generates 250 megawatts of electricity using Texaco/GE gasification technology.



The Puertollano IGCC power plant in Spain is the world's largest coal-based IGCC plant at 330 megawatts capacity. It is owned and operated by the ten-company ELCOGAS consortium. The plant employs the Uhde Prenflo technology to gasify a mixture of coal and petroleum coke feedstock.

The Shell Pernis Refinery in Rotterdam employs the Shell Gasification Process to convert heavy refining residues into hydrogen for a hydrocracker as well as syngas for power generation. The three gasifiers are integral process units for the Pernis complex and gasify 1,650 tons per day of residues. The unit started operation in 1997.

# INTRODUCTION

*The 2004 World Gasification Survey was designed to gather accurate information on the world gasification industry as it exists today and to also identify planned capacity additions.*

Prior to 1999, no organized database or centralized source of information existed to provide quick access to information on the global gasification industry. In 1999, the U.S. DOE—in conjunction with SFA Pacific and with the cooperation of the Gasification Technologies Council and its members—conducted the first survey. The information was collected from contacts with leading industry and government officials and reference materials such as gasification conferences; installation lists from licensors of gasification technology; lists from contractors and technology suppliers associated with the engineering and construction of gasification facilities; and a number of gasification guidebooks, studies, and feature articles. Once collected, the survey information was assembled into a database for public use. The 1999 survey results were also summarized and published in 2000 in a brochure entitled "Gasification: Worldwide Use and Acceptance."

The gasification database was updated in 2001 but, while the database was again made available for public use, no brochure was published.

This 2004 World Gasification Survey—the second update of the initial 1999 survey—was completed by Childress Associates in collaboration with members of the Gasification Technologies Council. It involved all major gasification technology vendors, suppliers of supporting technologies, and owners/operators of gasification-based power and manufacturing plants. The survey was generally restricted to commercial operating plants with a capacity exceeding 100 megawatts electric equivalent (MWe) to avoid the inclusion of pilot test and temporary facilities as valid contributors to the commercial experience database. All feedstocks were included—coal, petroleum residues, secondary materials, biomass, and other carbonaceous materials—to the extent that the facility in question met the minimum capacity requirement.

The 2004 database presents the survey information a little differently than in the past. Past databases included non-operating plants and plants under construction in the syngas capacity figures. However, the 2004 database includes only operating plants. That is one reason why the number of plants decreased since the last update, even though the syngas capacity increased. In addition, adjustments were made to the database as appropriate to account for the closing and re-categorization of gasification plants.

Furthermore, a direct comparison of the facilities included in the 2004 survey is difficult because the gasification plants use a variety of feedstocks and generate several different types of products. However, this issue has been addressed by using a measure of the production capacity of synthesis gas—namely megawatts thermal ($MW_{th}$) of syngas output—as the common basis of reporting, accumulating totals, and comparisons. The $MW_{th}$ unit is used consistently throughout this document (except in the Afterword). For purposes of comparison, the reported 2004 world syngas capacity of approximately 45,000 $MW_{th}$ is the equivalent of more than 25,000 MWe. In general, determining an equivalent product capacity depends upon differing assumptions for the variety of processing technologies used downstream of the gasifier.

Finally, the results of the survey for planned growth from 2005 to 2010 are affected somewhat by the unreported capacity data for several large coal-based power plants projected for construction in the U.S. For these projects, capacity figures were not supplied by the vendor/sponsor contacts in the 2004 survey and, therefore, were not included in world capacity totals. These projects were included, however, in the numbers of plants. Indicators of size for some of these plants have been made available since the 2004 survey and are now provided in the Afterword section.

The Nuon Power Buggenum IGCC plant, located in the Netherlands, gasifies a combination of coal and biomass/wastes using the Shell Coal Gasification Process. The 253 MW plant started up in 1993 as the Demkolec IGCC demonstration. The demonstration program was completed in 1998. Nuon Power Buggenum purchased the plant in 2001 and is testing various coal/biomass feedstocks.

At the Wabash River Repowering IGCC plant in Indiana, coal is gasified in an oxygen-blown, entrained-flow gasifier with continuous slag removal and a dry particulate removal system. The combustion turbine generates 192 MW and the repowered steam turbine provides another 104 MW. With a system parasitic load of 34 MW, net power production is 262 MW.

The Coffeyville Resources nitrogen plant in Kansas uses the GE Energy gasification process to convert 1,000 tons per day of petroleum coke from an adjacent refinery into syngas to produce 700,000 tons of nitrogen fertilizer a year. The plant started up in 2001 and has remained competitive in the ammonia market while other U.S. ammonia plants have been shutting down due to high natural gas prices and foreign competition.

## Cinergy/PSI, General Electric, and Bechtel to Explore Building Cleaner Coal Power Plant

Cinergy/PSI, General Electric Company, and Bechtel Corporation signed a letter of intent in 2004 to study the feasibility of constructing a commercial IGCC power generating station. PSI Energy, the Indiana operating company of Cinergy Corp., will own and operate the facility which will produce 500 to 600 megawatts of electricity. The letter of intent is the first step toward reaching a contract to design and construct the plant. Prior to this, GE and Bechtel announced their intent to develop a standard commercial offering for IGCC projects in the United States. GE Energy recently purchased the ChevronTexaco gasification business, whose technology has been applied to many of the world's gasification combined-cycle plants.

*"Given the high price of oil and the limited supplies of natural gas available, coal is the most practical alternative. Our challenge is to find ways to use an abundant resource in an economic and environmentally clean way. Coal gasification has proven to be efficient, and there is no cleaner coal technology."*

James Rogers, Chairman and Chief Executive, Cinergy Corp.

*"We are very pleased to be participating in the beginning stages of this important project. The Cinergy proposal is clear evidence of the growing interest in this technology among utilities and power developers across the U.S. power sector today."*

John Rice, Vice Chairman of General Electric and President/Chief Executive Officer of GE Industrial

*"We look forward to working with GE and Cinergy to make this IGCC project a reality for reliable, affordable, clean electricity. The current environmental benefits of this technology, coupled with the potential to meet future environmental regulations at a lower cost to the customer, can lead to the successful commercialization of an advantaged clean coal power plant for Cinergy."*

Scott Ogilvie, President of Bechtel Power Corporation

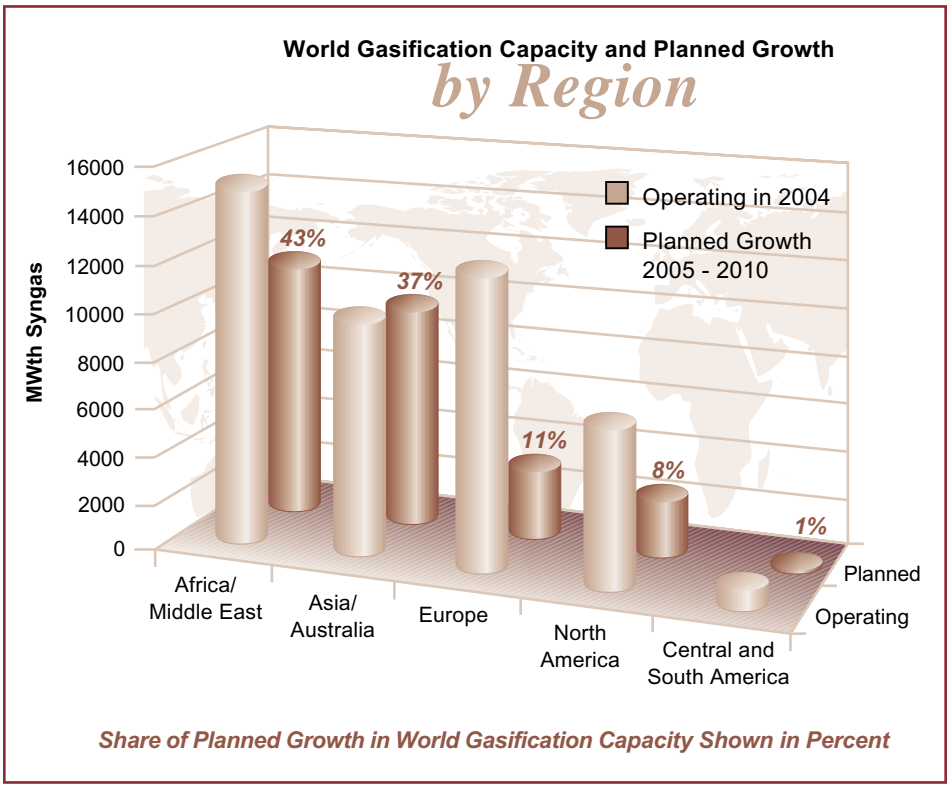
# SYNGAS PRODUCTION IN 2004

*South Africa and China are the dominant syngas-producing countries in the world. The three Sasol plants in South Africa account for one-third of world gasification capacity. China has 22 operating gasification plants with a total syngas output of about 30% of the worldwide capacity.*

The survey results are presented below showing the state of the industry in 2004 by geographical region, feedstock, product, and technology.

## Syngas Capacity by Region

The 2004 World Gasification Survey reported that existing world gasification capacity has grown to 45,001 $MW_{th}$ of syngas output from 117 operating plants and 385 gasifiers. Based on operating plants, Africa/Middle East is now the leading region in the world for gasification capacity. The European region—including Western Europe, Eastern Europe, and Russia—is the second largest, followed by Asia/Australia and then North America. Central/South America has very limited existing capacity.




*Share of Planned Growth in World Gasification Capacity Shown in Percent*

*North America*

As shown in the "Region" chart, North America currently has a syngas capacity of 6,697 $MW_{th}$, a 15% share of the world total. All of this activity resides in the United States, where 20 gasification-based plants are operating:

- Seven plants are in operation, fed by coal and/or petroleum coke. Three produce power, three produce chemicals and fertilizers, and one produces substitute natural gas. Among these are two Integrated Gasification Combined-Cycle (IGCC) power plants—Wabash River and Polk—built during the 1990s, the Eastman Chemical coal-to-chemicals plant, and the Basin Electric Great Plains plant, the only plant in the world producing pipeline quality gas. This last plant has also begun a program to capture and ship $CO_2$ via pipeline to Canada for sequestration and enhanced oil recovery.
- Four petroleum-based liquids plants produce chemicals or syngas for resale.
- Nine natural gas facilities primarily produce chemicals.

*Africa/Middle East*

Three Sasol plants in South Africa, which produce clean fuels and chemicals from coal, account for one-third of world gasification capacity. These plants employ 107 gasifiers, 28% of the world total. The first Sasol plant was built in South Africa in 1955, with additional facilities coming on line in 1977 and 1982. Those plants have been continually upgraded and today

process nearly 90,000 tons of coal per day. A much smaller gasification plant, which began operation in Egypt in 1966, produces fertilizers today from refinery residues and off-gases. The Africa/Middle East region has a syngas capacity of 15,173 $MW_{th}$, a 34% share of the present world gasification capacity.

*Europe*

With 48 operating gasification plants, the European region is the most diverse in terms of feedstocks, technologies, and products. The most recently built European gasification facilities primarily use petroleum-based feedstocks, with the exception of two biomass-based plants in Finland, the Nuon Buggenum coal-based IGCC facility in the Netherlands, and the Puertollano coal/petcoke-based IGCC plant in Spain. A number of older coal/lignite gasification plants, primarily in Eastern Europe, are also still operating. European capacity distribution in 2004 is as follows:

- Czech Republic—one petroleum-based plant produces chemicals and one coal-based plant produces power.
- Former Yugoslavia—two plants are in operation (one coal-based and one using natural gas) and produce chemicals.
- Finland—five plants that began operation between 1965 and 2001 produce gaseous fuels and power and use biomass/wastes as their primary feedstock. One plant gasifies petroleum (bunker fuel) to produce chemicals.
- France—two natural gas plants produce chemicals.
- Germany—twenty plants are in operation (one coal-based, four using wastes, 14 petroleum-based, and one using natural gas), with 14 producing chemicals, one producing gaseous fuels, and five primarily producing power.
- Italy—five plants are operating, with three using refinery residues as feedstock to generate electricity in combined-cycle plants and to produce some hydrogen for refinery use. Two older plants use natural gas to produce chemicals.
- Netherlands—three plants are operating, with two of worldwide significance. The Nuon Buggenum IGCC plant is one of three constructed during the 1990s that provide the operating experience necessary to construct the next generation of solid feedstock-based IGCC plants. (The other two—Polk and Wabash River—are in the U.S.) The third plant is a petroleum residue facility at the Pernis refinery which produces power, steam, and hydrogen for use in the refinery. Because of the energy efficient utilization of environmentally detrimental wastes, the Pernis plant could act as a template for other "green" refineries in Europe and around the world.
- Portugal—one petroleum-based plant produces chemicals and one biomass plant produces gaseous fuels.
- Spain—one coal-based plant produces power and one natural gas plant produces chemicals.
- Sweden—two biomass plants produce power and gaseous fuels and one petroleum-based plant produces chemicals.
- United Kingdom—two natural gas plants produce chemicals.

The European region has a syngas capacity of 12,382 $MW_{th}$, a 28% share of the world gasification capacity.

*Asia/Australia*

China began constructing gasification plants in the mid-1980s and now has 22 operating plants that convert coal and petroleum residues into a variety of chemicals, fertilizers, and gaseous fuels. Twelve

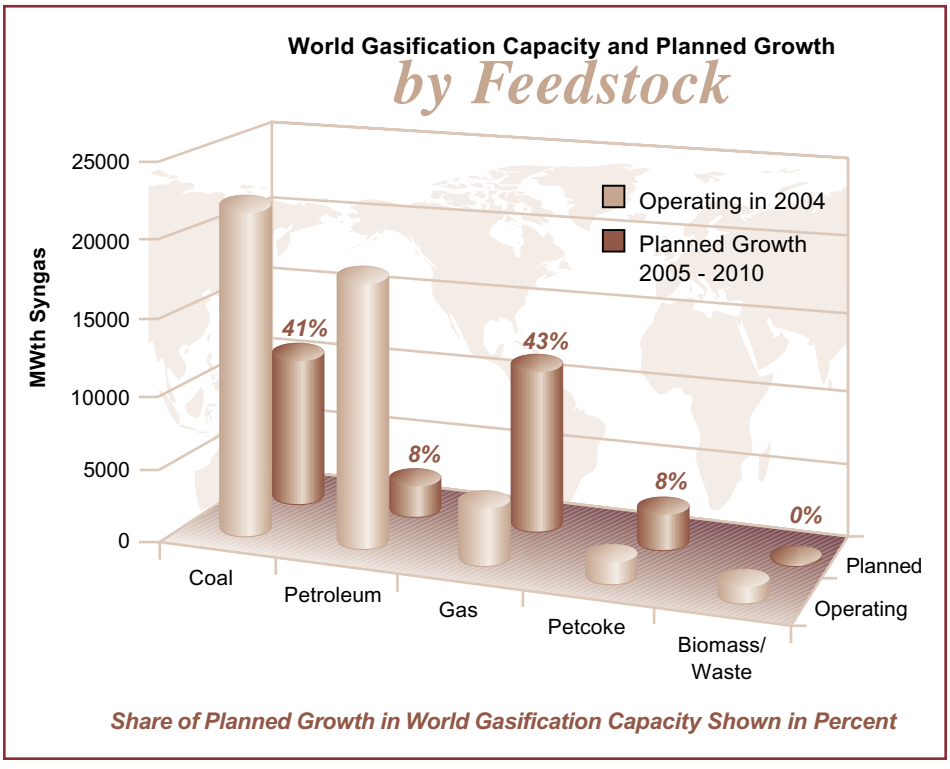
of these plants use liquid feedstocks, nine use coal, and one uses natural gas. However, no gasification-based power plants are currently operating or have been announced in China despite the abundance of gasification facilities. Other countries with gasification-based capacity in the Asia/Australia region include:

- Australia—one natural gas plant produces chemicals and $CO_2$.
- Singapore—two petroleum residue plants produce chemicals and power.
- Malaysia—one natural gas plant produces Fischer Tropsch liquids. This plant is a forerunner to the very large facility planned in Qatar that will use natural gas and produce Fischer-Tropsch distillate liquids.
- South Korea—three naphtha and petroleum residue plants produce chemicals and fertilizers.
- Taiwan—two naphtha and petroleum residue plants produce chemicals.
- Japan—five petroleum coke and coal plants produce chemicals and one petroleum residue plant produces power. The Nippon Petroleum Refining Company built the power-producing plant at their Negishi refinery and started operations in 2003 as the first IGCC in Japan. The Negishi plant may provide a working template for the Japanese refining industry since the Basic Energy Plan completed by the Japanese government in 2003 places increased emphasis on gasification of petroleum residues.
- India—five petroleum-based feedstock plants produce chemicals and fertilizers and one solid feedstock (lignite/petcoke) plant produces electricity. The lignite/petcoke plant is still operating on naphtha as the initial phase of operation, but the gasification unit capable of using lignite/petcoke will be installed during a future phase.

The Asia/Australia region has a 22% share of the present world gasification capacity, with a syngas capacity of 10,101 $MW_{th}$.

*Central/South America*

The survey results show that the Central/South American region significantly lags other world regions with a syngas capacity of just 648 $MW_{th}$, a 1% share of the world gasification capacity. Two petroleum-fed plants are currently operational in Brazil and the Dominican Republic, producing chemicals and gaseous fuels.




*Share of Planned Growth in World Gasification Capacity Shown in Percent*

## Syngas Capacity by Feedstock

Gasification facilities consume a variety of carbon-based feedstocks, including natural gas, coal, petroleum, petcoke, biomass, and industrial wastes. From the 2004 survey, the "Feedstock" chart shows that coal now dominates as the feedstock in more than 49% or 22,143 $MW_{th}$ of syngas capacity, representing 22 plants. Petroleum (including fuel oil, refinery residue, and naphtha) is the second leading feed-

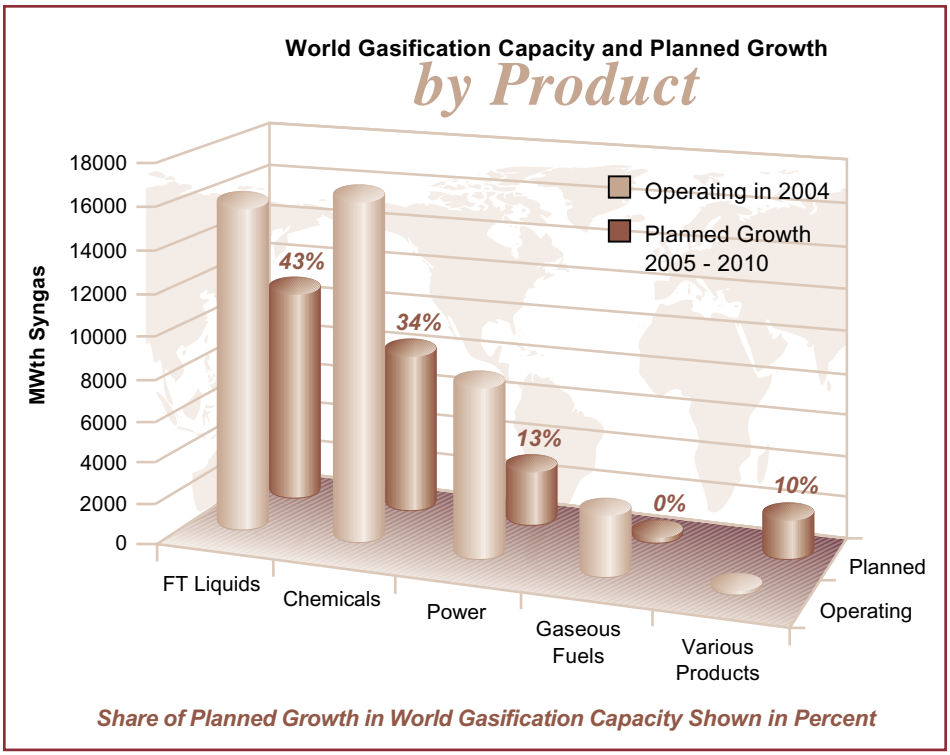
stock, with 16,391 $MW_{th}$ or 37% of total gasification capacity covering 57 plants. Natural gas provides 9%, with petcoke and biomass/waste offering 3% and 2%, respectively. As a diverse feedstock, coal continues to be used for power generation as well as to produce chemicals, Fischer Tropsch liquids, and gaseous fuels.

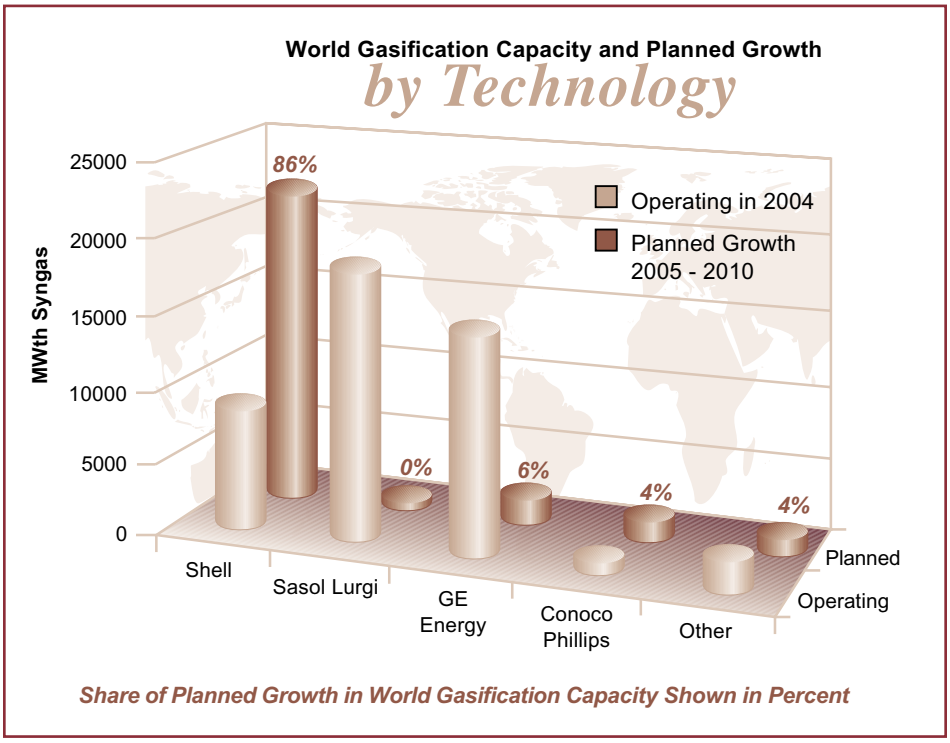
## Syngas Capacity by Product

The versatility and flexibility of gasification plants enable them to offer a wide range of products including Fischer Tropsch liquids, chemicals, fertilizers, power, steam, gaseous fuels, and various other products (e.g., ammonia and hydrogen). The "Product" chart shows that, for operating plants identified in the 2004 survey, chemicals and Fischer Tropsch liquids represent the leading products with 37% and 36%, respectively, of the world gasification capacity. Chemicals are generated at 81 plants and Fischer Tropsch liquids at four plants. Other products are power (19%) and gaseous fuels (8%). Power generation occurs presently at 21 gasification plants worldwide.

## Syngas Capacity by Technology

The 2004 survey revealed that more than one dozen different gasification technologies are now in operation in plants around the world. However, three commercial technologies are currently dominant and hold 94% of the 2004 world market. As illustrated in the "Technology" chart, Sasol Lurgi (dry ash) gasifiers lead the way with eight plants, accounting for 41% of world gasification capacity or 18,637 $MW_{th}$ of syngas output. GE Energy gasifiers are used at 64 plants, representing 34% (15,109 $MW_{th}$) of the total, and Shell gasifiers are used at 26 plants, representing 19% (8,516 $MW_{th}$) of total syngas output. The remaining 6% is spread among a dozen other gasification technologies.



# GROWTH PLANNED THROUGH 2010

*Twenty-four new plants are planned in China, which will result in a 93% syngas capacity increase for the Asia/Australia region. In terms of product, Fischer Tropsch liquids will have the largest share of planned growth, most of which is from a single gas-to-liquids project in Qatar.*

World syngas capacity is projected to grow 25,282 $MW_{th}$, an increase of 56%, from 2005 to 2010. The survey results show planned growth in gasification capacity from 2005 to 2010 by region, feedstock, product, and technology.

## Syngas Capacity Growth by Region

The "Region" chart in the previous section shows planned growth in gasification capacity for each major region of the world from 2005 to 2010. The chart also shows the percentage distribution or relative share of the total worldwide growth by region.

### *North America*

Growth in the North American region is expected to exceed 31% from 2005 to 2010 and will come from six announced projects in the U.S. and one in Canada. The six U.S. projects will use solid feedstocks (coal and/or petroleum coke) to generate electricity and other co-products—hydrogen, ammonia, chemicals, fertilizer, and/or Fischer Tropsch liquids. Preliminary plans have also been announced for additional coal-based IGCC projects in the U.S. primarily for power generation (see Afterword section), but there was insufficient detail to include them in these survey results. Two of these projects—announced by major utilities American Electric Power (AEP) and Cinergy Corporation—are advancing in early planning or feasibility stages.

In Canada, the country's first gasification-based facility—the Long Lake Plant, associated with oil sands production—is under construction. The goal is to gasify low/negative value feedstocks (asphalt and/or petroleum coke) now being produced as a byproduct of extraction and upgrading of the oil sands. Hydrogen, steam, and power produced by the gasification plant will be used to produce and upgrade the synthetic crude oil extracted from the tar sands. Other oil sands-related gasification projects are in preliminary analysis and planning stages. The primary driver is high natural gas prices in Canada as well as in the rest of North America. Given the expected strong growth in demand for synthetic crude from oil sands in Canada, this is expected to be a strong future market for gasification.

### Natural Gas Plant in Qatar

The 11,000 $MW_{th}$ Qatar gas-to-liquids plant, planned for 2009 operation, was not ready to be reported during the 2001 survey update. Therefore, it is a significant reason for the overall increase in planned capacity between the 2001 and 2004 survey updates. The huge Qatar plant is being designed to take advantage of a similarly huge, and therefore unique, natural resource in Qatar: natural gas. This plant is not expected to be the beginning a significant new trend in gasification.

In 2003 the Nippon Petroleum Refining Company Negishi IGCC plant began operations. The 342 megawatt plant is the first IGCC in Japan and gasifies 2,000 metric tons per day from the Negishi refinery in Yokohama.

The Dakota Gasification Great Plains Synfuels Plant uses Sasol Lurgi technology to gasify almost 14,000 tons per day of lignite to produce almost 150 million standard cubic feet of substitute natural gas. The plant has been in operation since 1984 and is the only commercial scale plant in the U.S. to produce pipeline quality gas. The plant is now also exporting up to 95 million cubic feet of $CO_2$ per day to Canada for enhanced oil recovery/carbon sequestration.

*Africa/Middle East*

Capacity in the Africa/Middle East region is expected to grow by 72% from 2005 to 2010 based on the Shell gas-to-liquids project in Qatar which will produce 140,000 barrels per day of distillate fuel. Planned for operation by 2009, this project will use gasification technology to convert natural gas to synthesis gas and then use Fischer Tropsch conversion technology to produce clean diesel fuel. As a result of this very large plant in Qatar, this region will likely continue to dominate gasification-based capacity in the near future.

*Europe*

European capacity is expected to grow by 23% from 2005 to 2010 with the addition of more than 2,800 $MW_{th}$ from four plants producing primarily power. Two of the four plants (in Poland and Italy) will use refinery residues for polygeneration of power and hydrogen. One planned IGCC facility in Italy will use coal to generate electricity and one lignite IGCC plant is planned in the Czech Republic as an addition to the current power plant (Vresova) for greater power generation. No new plants are planned during 2005 to 2010 for any other European countries.

*Asia/Australia*

Syngas capacity growth in Asia/Australia will be the strongest of all world regions, with new plant capacity plans for 2005 to 2010 totaling 9,367 $MW_{th}$—a growth rate for that region of 93% from its 2004 level of 10,101 $MW_{th}$. This growth will be comprised of 25 plants that will gasify coal or petroleum coke. Twenty-four of the plants will be in China, all processing coal to produce chemicals, methanol, and fertilizers. The Chinese government is said to be currently considering a commitment to 10% IGCC-based power in future coal-based plants. One additional plant in the Asia/Australia region will be in India at the Orissa refinery where petroleum coke will be gasified starting in 2006 to produce power and hydrogen—a configuration similar to the Shell Pernis refinery in the Netherlands.

*Central/South America*

Capacity growth in the Central/South American region of 10% from its 2004 level of 648 $MW_{th}$ is projected to come from one new biomass plant in Brazil that will generate electricity beginning in 2006.

## Syngas Capacity Growth by Feedstock

The "Feedstock" chart in the previous section illustrates expected growth in world gasification capacity based on feedstock distributions. Natural gas leads all feedstocks with 43% of the total planned growth from 2005 to 2010, based on the natural gas to Fischer Tropsch fuels plant in Qatar. Coal is second with 41%. Major new coal-based power plants are being projected for 2008 to 2010 at greenfield locations in the U.S. and can be expected to set the pace for more of these facilities beyond 2010. Beyond the new plants announced in the 2004 survey, additional new coal-based IGCC power plants are anticipated at both greenfield and brownfield sites as indicated in the Afterword section.

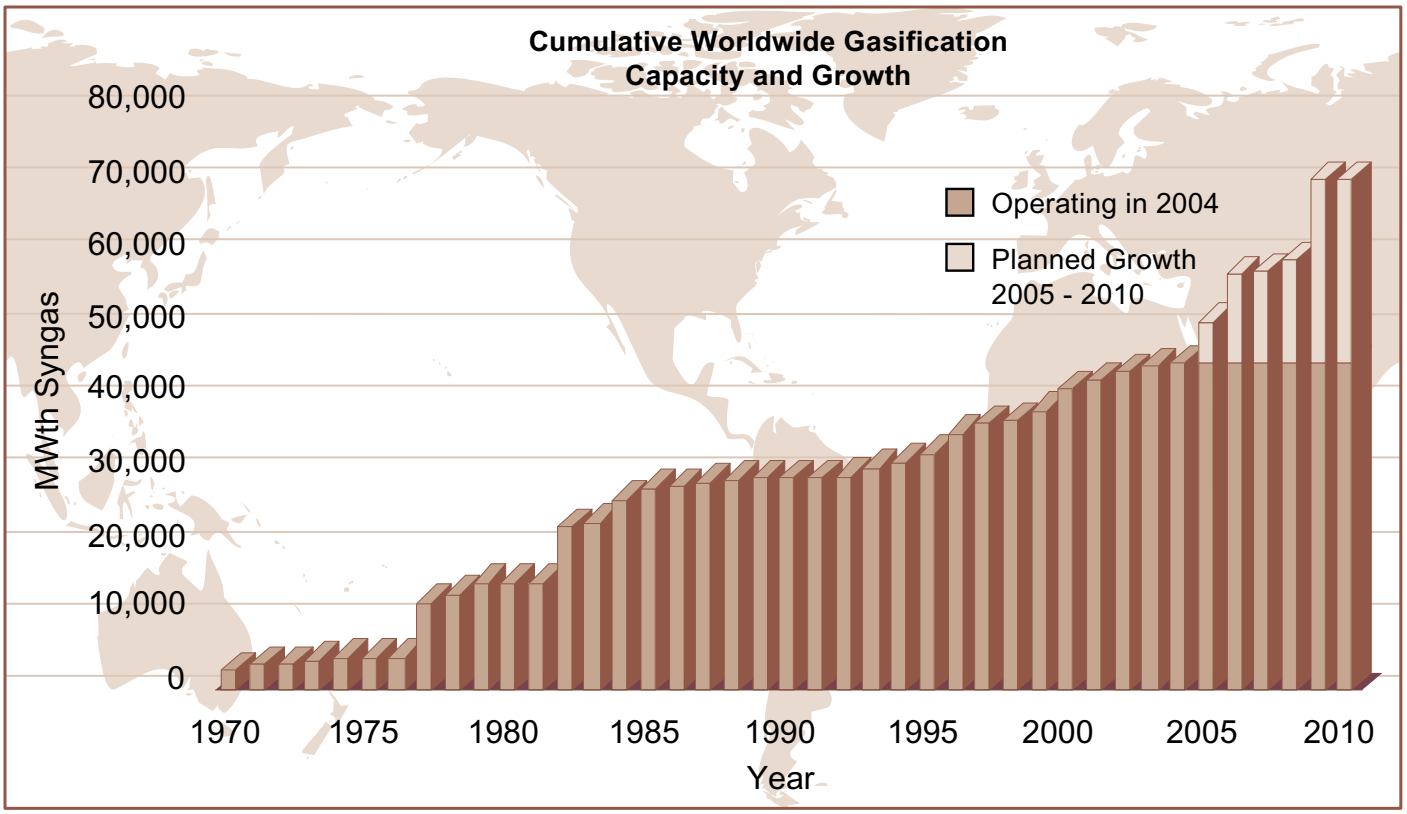
Petroleum residues and petcoke will provide about one-sixth of new capacity planned by 2010, although prospects are strong for additional significant growth from the Canadian oil sands industry and petroleum refining in the U.S. Planned petcoke capacity will grow in the U.S., with petroleum residues originating in the Canadian oil sands industry. Growth in natural gas feedstocks will primarily be from remote gas in the Middle East.

## Syngas Capacity Growth by Product

For planned growth between 2005 and 2010, Fischer Tropsch liquids continue to account for the largest share of worldwide growth in gasification capacity, with 43% of the total. The "Product" chart in the previous section shows that production of chemicals is expected to account for 34% of planned worldwide growth in capacity. Power generation remains third at 13%, with various other products accounting for 10%.

## Syngas Capacity Growth by Technology

As evident from the "Technology" chart in the previous section, Shell may achieve more than 86% of the planned growth in total syngas capacity during the period 2005 to 2010 on the basis of the large Fischer Tropsch distillate liquids plant in Qatar and the large number of coal-based chemicals plants in China. If this occurs, Shell gasifiers will account for 43% of the total world market by 2010, Sasol Lurgi will slip to a market share of 27%, and GE Energy gasifiers will decline to 24% of the world market. The survey indicates that many of the planned gasification plants will select high-temperature, oxygen-blown, slagging entrained gasifiers—such as those supplied by Shell, GE Energy, ConocoPhillips, GSP, and others—as the technology of choice from 2005 to 2010.




## Gasification – A Half-Century of Success

The "Cumulative Worldwide Gasification Capacity and Growth" chart provides an historic view of gasification use for the last 35 years. This chart shows an industry realizing long-term continuous growth and expanding opportunities, including substantial contributions to world energy needs. Beginning in the 1950s, gasifiers were employed to produce chemicals and fertilizers from a variety of low cost feedstocks including coal or petroleum residues. The first substantial rise in gasification use occurred in the 1970s and then again in the 1980s in response to the rise in energy prices which made lower cost, less desirable feedstocks attractive economic alternatives to increasingly expensive petroleum and natural gas. During the 1990s, gasification enjoyed even more robust growth, with worldwide capacity increasing by almost 50% during the decade. The reason for this long-term and continuing growth is clear: modern, high temperature slagging gasifiers have the ability to convert low value feedstocks into higher value products—chemicals, fuels, and electricity—while meeting the most demanding environmental standards for air emissions, solids, water use, and $CO_2$ removal from the product gas.

# RECENT INDUSTRY CHANGES AND HOW THEY MAY IMPACT THE FUTURE

*The 2004 survey projects that 38 new gasification plants will start operations from 2005 through 2010. However, actual construction of some of these plants, particularly the coal-based power plants in the United States, may be linked to the cost of natural gas.*

This section explains how the gasification industry has changed during the last five years based on 2004 survey results, compares current industry plans for new gasification facilities with 1999 and 2001 growth projections, and describes recent developments or trends in the gasification industry.

## Recent Changes in World Syngas Capacity

The 2004 World Gasification Survey indicates that existing world gasification capacity has grown to 45,001 $MW_{th}$ of syngas output from 117 operating plants and 385 gasifiers. Compared to the prior 1999 survey level of 42,726 $MW_{th}$ reported, this represents a 5% increase in syngas output.

Focusing on the 2000 to 2004 period, 18 new gasification plants began operating and now provide 6,410 $MW_{th}$ syngas capacity. They are about evenly distributed in capacity between six power plants (56%) and 12 chemical production plants (44%). Of these 18 plants shown in the "Gasification Plants Started During 2000 to 2004" table, 16 use high-temperature entrained-flow slagging gasifiers. These new plants primarily use petroleum residuals and petcoke as feed. The gasifiers selected are primarily Texaco designed and developed versions of high-temperature entrained-flow slagging gasifiers. In 2004, the ownership of the technology changed and is now held by GE Energy.

### *Syngas Capacity Changes by Region*

The top two regions of the world in syngas output capacity have switched places in the last five years. Africa/Middle East (34%) is now the leading region in the world for gasification based on operating plants, replacing the combined region of Western Europe and Eastern Europe (including the former Soviet Union), which led the world in total syngas output in the 1999 survey. The European region (28%) is now the second largest region, followed by Asia/Australia (22%), North America (15%), and Central/South America (1%). In the 1999 survey, the Africa/Middle East and Asia/Australia regions were in a virtual tie for second place, followed by North America and Central/South America.

### *Syngas Capacity Changes by Feedstock*

During the last five years, coal increased its lead as the dominant feedstock for gasification plants from 42% to 49% of total world capacity. As shown in the "Gasification Plants Planned for 2005 to 2010" table, most new plants—29 of the 38 planned for

## Gasification Plants Started During 2000 - 2004

| Year | Plant Name/Owner | Country | Feedstock | Product | MWth Output |
|---|---|---|---|---|---|
| 2000 | Linde AG | Singapore | Petroleum | Chemicals | 220 |
| 2000 | Coffeyville Resources Refining and Marketing, LLC | United States | Petcoke | Chemicals | 293 |
| 2000 | Henan | China | Coal | Chemicals | 312 |
| 2000 | SARLUX srl | Italy | Petroleum | Power | 1,271 |
| 2000 | BOC Gases | Australia | Gas | Chemicals | 110 |
| 2000 | Huainan General Chemical Works | China | Coal | Chemicals | 191 |
| 2000 | EPZ | Netherlands | Biomass/Waste | Power | 84 |
| 2000 | ExxonMobil | United States | Petroleum | Gaseous fuels | 347 |
| 2000 | DEA Mineraloel AG | Germany | Petroleum | Chemicals | 205 |
| 2001 | api Energia S.p.A. | Italy | Petroleum | Power | 526 |
| 2001 | Jilin Chemical Industrial Corp. | China | Petroleum | Chemicals | 287 |
| 2001 | Esso Singapore Pty. Ltd. | Singapore | Petroleum | Power | 364 |
| 2001 | Corenso United Oy Ltd. | Finland | Biomass/Waste | Gaseous fuels | 32 |
| 2002 | Premcor, Inc. | United States | Petcoke | Power | 520 |
| 2002 | Nanjing Chemical Industry Co. | China | Petroleum | Chemicals | 301 |
| 2002 | IBIL Energy Systems Ltd. (IES) | India | Coal | Power | 109 |
| 2002 | Air Liquide America Corp. | United States | Gas | Chemicals | 213 |
| 2003 | Nippon Petroleum Refining Co. | Japan | Petroleum | Power | 793 |
| 2004 | BP/Formosa | Taiwan | Petroleum | Chemicals | 148 |
| 2004 | Haolianghe Ammonia Plant | China | Coal | Chemicals | 202 |

the period 2005 to 2010—intend to use coal as the feedstock. Petroleum (including fuel oil, refinery residue, naphtha, etc.) is still the second leading feedstock with 37% of total gasification capacity from 57 plants, but its share has declined from five years ago when it was at 42% based on 56 plants. Natural gas remains the third-ranking feedstock at the same 9% level of total capacity as in 1999. Petcoke and biomass/waste also retained their fourth and fifth-place rankings with 3% and 2%, respectively.

## Gasification Plants Planned For 2005 - 2010

| Year | Plant Name/Owner | Country | Feedstock | Product | MWth Output |
|---|---|---|---|---|---|
| 2005 | AGIP Raffinazione S.p.A. | Italy | Visbreaker residue | Power | 457 |
| 2005 | Sokolovska Uhelna, A.S. | Czech Republic | Lignite | Power | 787 |
| 2005 | Sinopec/Shell | China | Coal | Chemicals | 466 |
| 2005 | Sinopec/Shell | China | Coal | Chemicals | 466 |
| 2005 | Shuanghuan Chemical | China | Coal | Chemicals | 178 |
| 2005 | Liuzhou Chemical | China | Coal | Chemicals | 287 |
| 2005 | Sinopec-Shell | China | Coal | Chemicals | 273 |
| 2005 | Sinopec | China | Coal | Chemicals | 273 |
| 2005 | Sinopec | China | Coal | Chemicals | 465 |
| 2005 | Liuzhou Chemicals | China | Coal | Chemicals | 232 |
| 2005 | Shuanghuan Chemicals | China | Coal | Chemicals | 191 |
| 2005 | Anqing Sinopec | China | Coal | Chemicals | 465 |
| 2005 | China 1 (Expansion) | China | Coal | Chemicals | 280 |
| 2005 | China 2 | China | Coal | Chemicals | 174 |
| 2005 | Jinling | China | Coal | Chemicals | 287 |
| 2005 | China 3 | China | Coal, Petcoke | Chemicals | 287 |
| 2005 | China 4 | China | Coal, Petcoke | Chemicals | 287 |
| 2006 | ATI Sulcis | Italy | Coal | Power | 957 |
| 2006 | Indian Oil Corporation, Ltd. | India | Petcoke | Chemicals | 889 |
| 2006 | Sistemas de Energia Renovavel | Brazil | Biomass | Power | 68 |
| 2006 | Dahua Chemicals | China | Coal | Chemicals | 205 |
| 2006 | Yuntianhua Chemicals | China | Coal | Chemicals | 465 |
| 2006 | Yunzhanhua Chemicals | China | Coal | Chemicals | 465 |
| 2006 | Opti Canada | Canada | Asphalt | Various products | 1,025 |
| 2006 | Dahua Chemicals | China | Coal | Chemicals | 232 |
| 2006 | Yuntianhua Chemicals | China | Coal | Chemicals | 465 |
| 2006 | Yunzhanhua Chemicals | China | Coal | Chemicals | 465 |
| 2006 | Shenhua | China | Coal | Hydrogen | 861 |
| 2006 | China 5 | China | Coal | Chemicals | 284 |
| 2007 | Yongcheng Chemicals | China | Coal | Chemicals | 424 |
| 2008 | Global Energy, Inc. | United States | Coal, MSW | Power | 1,006 |
| 2008 | Vanguard Synfuels | United States | Petcoke | Various products | 0 |
| 2008 | Lotos Reffinery Gdansk | Poland | Asphalt | Various products | 620 |
| 2009 | Excelsior Energy | United States | Coal | Power | 0 |
| 2009 | Lake Charles Cogeneration LLC | United States | Petcoke | Various products | 0 |
| 2009 | Rentech Development | United States | Coal | FT liquids | 59 |
| 2009 | Qatar Petroleum | Qatar | Natural Gas | FT liquids | 10,936 |
| 2010 | Steelhead Energy | United States | Coal | Power | 0 |

Operating since 2000, the Brisbane Hydrogen Plant in Australia employs two GE Energy gasifiers with natural gas as the feedstock to produce chemicals.

The ExxonMobil Baytown Syngas Plant in Texas is a 240 MW facility that began operation in 2000. Petcoke is used as the feedstock for two GE Energy gasifiers at the plant, which produces both electricity and gaseous fuels.

### *Syngas Capacity Changes by Product*

The 2004 survey shows that chemicals remain the top product generated by gasification plants. However, its relative ranking declined from 43% to 37% since 1999. On the other hand, Fischer Tropsch liquids increased its relative position to 36% from a level of 25% five years ago. Much of this growth in Fischer Tropsch liquids is due to the gasification of natural gas at remote locations like the Shell Bintulu facility in Malaysia. Power or electricity generation is now at 19% of total world syngas capacity compared to a previous level of 25%. Gaseous fuels also declined slightly from 9% to the current 8% level. Most new projects planned for 2005 to 2010 intend to produce chemicals or generate power.

### *Syngas Capacity Changes by Technology*

In 1999, Texaco (now GE Energy) gasifiers provided 39% of world syngas capacity, Sasol Lurgi gasifiers provided 28% and Shell gasifiers provided 21%. The 2004 survey showed that three commercial technologies—Sasol Lurgi, GE Energy, and Shell—currently provide 94% of the world syngas capacity. Sasol gasifiers provide 41% of the gasification capacity, GE Energy gasifiers provide 34%, and Shell gasifiers provide 19%. The remaining 6% of capacity in 2004 is spread among a dozen additional gasification technologies. This shift in technology use may continue: about 63% of the new plants planned for the next five years (including the Qatar GTL plant) are projected to use Shell gasifiers, and 16% are projected to use GE Energy gasifiers.

## Comparison of Growth Projections

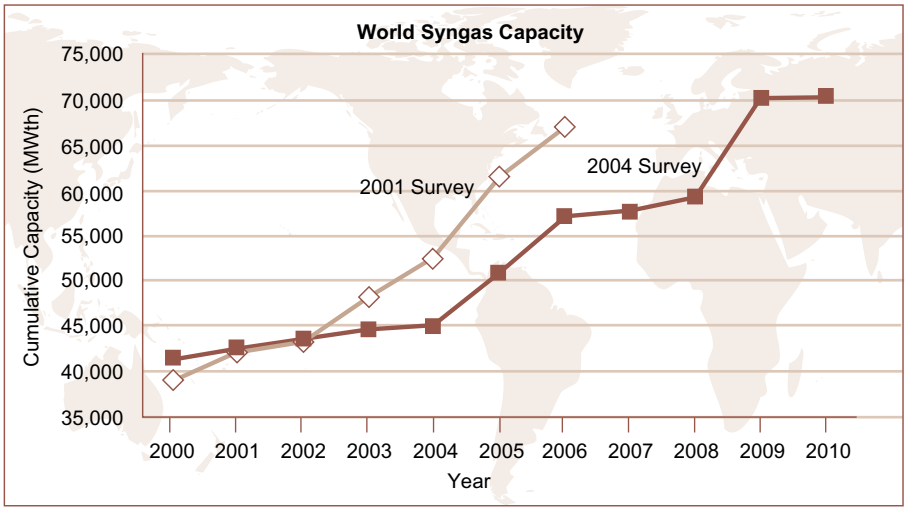
The "World Syngas Capacity" chart on the following page shows a predicted growth pattern from the 2001 survey against the actual growth that was reported in the 2004 survey. Obviously, the growth prediction of 2001 was not attained.

While the net syngas growth was less than expected, one region stands out as having made unexpected gains: in 1999 the Africa/Middle East region showed no expected growth for the next five years; however, the reported capacity of the South African Sasol gasifiers in 2004 had increased by over 40%.

Another local improvement was in the Asia/Australia region. The expanding economy in China has resulted in associated energy and chemical feedstock demand increases, where three coal-based gasification plants making ammonia and two petroleum-waste fed ammonia plants began operations during the last five years. In addition, a new IGCC plant operating in Japan is likely to serve as a template for more refinery-based gasification plants in Asia.

However, many 2001 plans to build new gasification plants in Western Europe and North America were abandoned or postponed. This can be primarily attributed to an economic decline from 2000 to 2001, which resulted in:

- Reduced demand for electricity, chemicals, and fuels below expected levels which, in turn, resulted in the delay or cancellation of several gasification projects as well as other energy-related projects.




- Increased unwillingness or hesitancy in the investment community to commit large amounts of funding to capital-intensive, long-term energy projects such as gasification-based plants.

- Reduced demand for and the price of natural gas in the U.S. and around the world, especially affecting coal-based gasification projects in the U.S. that could not compete with lower priced natural gas-based generation. Although natural gas costs began increasing in 2002, they did not reach sustained levels that would support gasification investments until late 2003.

Globally, the results of the 2004 survey show a gasification capacity growth rate similar to that predicted in 2001, as a result of improved economic conditions. In essence, the growth expected in 2001 has shifted about three to five years into the future.

## Trends and Drivers in the Gasification Industry

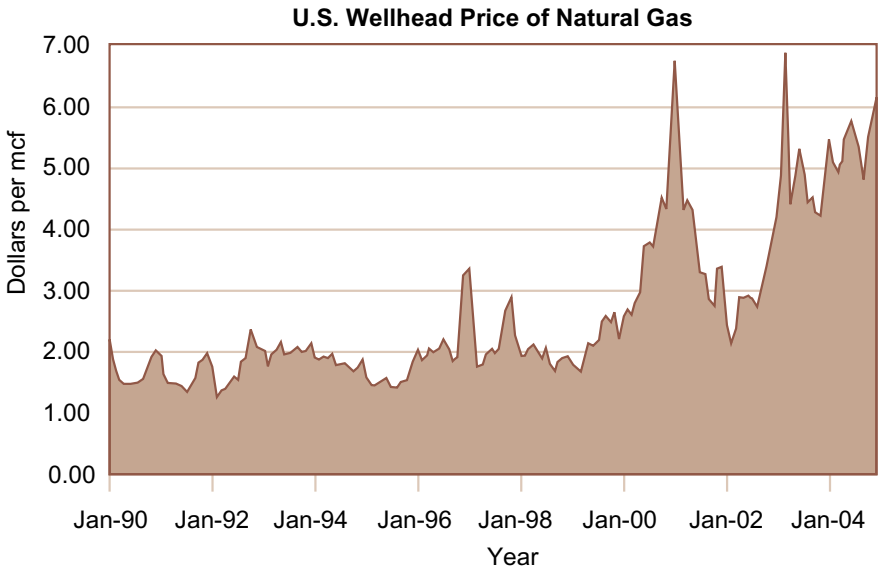
Some recent trends in the gasification industry are important to recognize since they will likely have a continuing impact on the future direction and growth of the industry.

### *Influence of Natural Gas Prices on Gasification-Based Power Plant Plans*

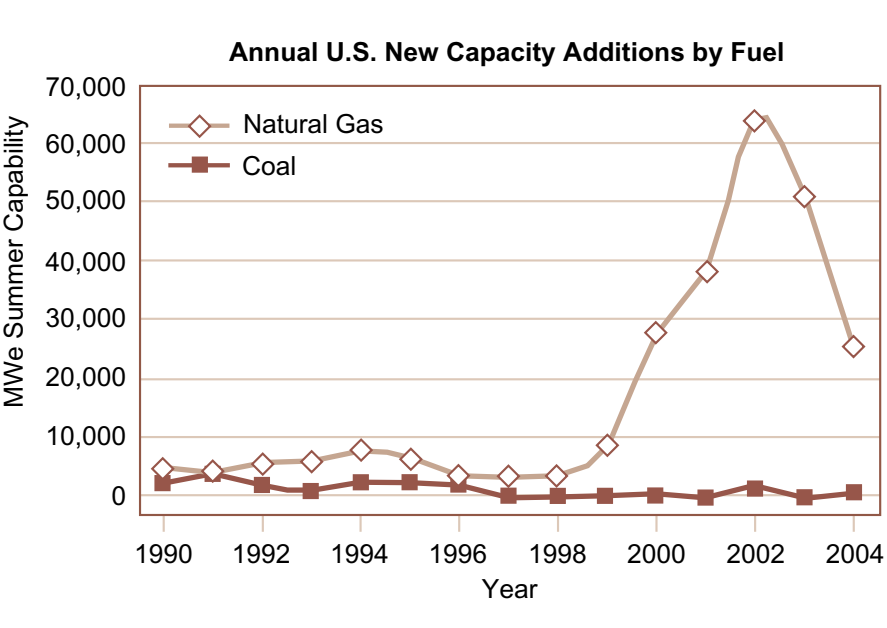
The cost of natural gas has been shown to have a major impact on plans to build gasification power plants in the U.S. Between 1999 and 2004, natural gas was readily available at a relatively low cost for new power capacity in the U.S. However, due to transportation limitations for natural gas, it is not generally a global commodity. Thus, sensitivity to natural gas prices is largely dependent upon the geographical location and the availability of natural gas in that country. For example, an excess of available natural gas has led to plans for

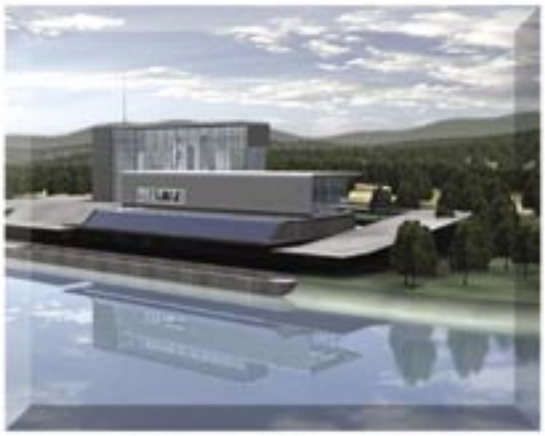
the large natural gas plant in Qatar. On the other hand, in North America natural gas is a swing fuel with marginal availability and price sensitivities.

Between 1990 and 2000, natural gas prices in the U.S. generally hovered around $2.00 per thousand cubic feet (mcf) as indicated in the "U.S. Wellhead Price of Natural Gas" chart, which put coal at a significant economic disadvantage in the power generation market. This, coupled with energy policies favoring gas use, led to a rapid increase in the use of gas to produce power, as illustrated in the "Annual U.S. New Capacity Additions by Fuel" chart. Natural gas demand outstripped production growth, resulting in a sharp increase in gas prices in 2002 and in expanded plans for gasification power generation. When prices dropped in early 2002, those plans were scaled back. Since 2002, however, the increase in gas price levels—currently in excess of $11.00 per mcf—and the expectation of continued high prices favor gasification expansion. As a result, numerous coal or petroleum coke-based gasification combined-cycle power plants are planned in the U.S. The expanded interest in gasifying solid feedstocks to produce synthesis gas rather than using more-expensive natural gas is readily evident in the chemicals and hydrogen supply plants that have been built recently.




*Source: U.S. Energy Information Administration*





## Change in Technology Ownership Reshapes Gasification Industry

Since the last update of the world gasification database there have been significant changes in ownership of some major gasification technologies.

- In December 2002, Future Energy GmbH acquired the GSP (formerly NOELL) gasification technology from BBP Power Plants GmbH. The GSP technology is employed at the Schwarze Pumpe gasification complex near Dresden, Germany.
- In July 2003, ConocoPhillips acquired the E-Gas technology from Global Energy, Inc.
- Also in July 2003, Allied Resource Corporation of Wayne, PA acquired the BGL gasification technology from Lurgi Lentjes AG.
- In June 2004, GE Energy, a division of the General Electric Company, acquired ChevronTexaco's gasification technology.

## American Electric Power to Build IGCC Units

American Electric Power (AEP) announced that it will build one or more IGCC units of 600 megawatts each in the company's eastern service area. AEP owns more than 36,000 megawatts of generating capacity in the U.S. and is one of the nation's largest electric utilities, with more than five million customers linked to its 11-state electricity transmission and distribution grid.

According to AEP, an IGCC plant is a good match for them because the technology works well with high-Btu coals such as the bituminous Appalachian coals readily available in AEP's eastern area. While the company has not yet made its final plant site selection, it has asked PJM, an independent transmission provider, to evaluate transmission interconnection feasibility for three potential sites on the Ohio River. In addition, AEP has begun the processes for siting, permitting, and seeking regulatory approval for cost recovery while it continues to evaluate plant sites.

*Increased Demand in Asia*

The expanded economy in Asia, particularly in China and India, has generated increased interest in gasification as a viable energy option. This can be seen by the large number of new operating gasification plants as well as by plants in the planning stages. Coal is readily available in those countries where oil and gas are not plentiful. The 2004 survey identifies more than 40 plants built between the mid-1980s and the time of the survey, most of which are producing chemicals. While this is already a large portion of the existing worldwide syngas capacity, the capacity is being expanded to a greater extent by 24 plants in the planning stage. Most of the new capacity in gasification plants in Asian countries, such as China and India, will be used for producing chemicals, fertilizers, and power. Accelerating demand for these products is expected to continue to be an important driver for the gasification industry, particularly as these countries pursue energy technology options that are well-suited for future environmental protection and for carbon control requirements.

*Power (Electricity, Steam, and Hydrogen) from Environmental Wastes*

During the last 20 years, industries such as petroleum refineries have attempted to more completely use the wastes from refining in order to avoid environmental issues associated with outdoor storage, runoff, and

discharges as well as the costs of disposal. At the same time, gasification can use these wastes to produce power, synthesis gas, and hydrogen for use in the refinery or for export from the plant. These are the primary reasons for increased interest in these plants, particularly in Europe (Italy, Poland, and the Netherlands) and the U.S. (Delaware). The 2004 survey has identified 10 plants producing power (with a capacity greater than 7,000 $MW_{th}$ syngas) from petcoke, asphalt, and oil process residuals that started operation between 1992 and 2003, plus two smaller plants (about 500 $MW_{th}$) started in 1968 and 1985. In addition, there are as many as seven power plants in the planning stage for startup from 2005 to 2010 that are expected to add identified capacity of about 4,000 $MW_{th}$ syngas.

# AFTERWORD

Since completion of the 2004 survey, there have been additional noteworthy market and public policy developments that will likely result in a significant increase in future coal and petroleum coke-based gasification capacity in the United States above the level suggested by the survey.

First, continued high petroleum and natural gas prices have resulted in a number of new gasification-based projects proposed in the U.S. since completion of the survey. Twenty-seven projects have been identified through a review of industry developments.

While it is unlikely that all of these projects will proceed to construction, the energy market—with petroleum prices peaking at more than $70 per barrel and natural gas exceeding $11.00 per mcf by September 2005—is providing a favorable climate for gasification-based power generation and polygeneration projects in the U.S.

Second, the passage of the Energy Policy Act of 2005 provides significant federal financial incentives for a wide variety of gasification-based projects in the U.S. The new law authorizes direct federal outlays of as much as $5.4 billion in grants, investment tax credits, loans, and cost sharing that could help fund an estimated 16 gasification-based plants. Additional authority was created for 80% loan guarantees for an estimated 17 additional gasification projects.

Third, the transportation bill—also passed and signed into law in August 2005—provides a 50-cent per gallon credit for coal-based Fischer Tropsch fuels produced and used in the U.S.

Finally, the expectations of more stringent environmental constraints and the potential requirements for carbon capture and sequestration have become more likely and more relevant to decision makers. The strategic choices for generation capacity for many decision makers are now influenced by the potential to adapt to these environmental and carbon policies. Gasification provides a versatile option to satisfy environmental and carbon policy requirements and is increasingly becoming the technology of choice.

This combination of favorable energy market conditions and strong public policy support establishes a foundation for significant additions to gasification capacity in the U.S. in the coming years for the production of clean power, fuels, and chemicals.

## Gasification-Based Projects in Development in the United States

| Project Owner | State | Fuel | Products | MWe * |
|---|---|---|---|---|
| American Electric Power | OH | Coal | | 600-1,200 |
| Baard Generation | OH | Coal | Polygen | 200 |
| Cash Creek Generation (Erora) | KY | Coal | | 675 |
| Clean Coal Power Resources | IL | Coal | | 2,400 |
| DKRW | WY | Coal | Polygen | 350 |
| Duke/Cinergy | IN | Coal | | 600 |
| Energy Northwest | WA | Coal | | 600 |
| Erora Group | IL | Coal | | 675 |
| Excelsior Energy ** | MN | Coal | | 530 |
| First Energy/Consol | OH | Coal | | 500 |
| Florida Power & Light | FL | Coal | | 850 |
| Global Energy Pioneer | KY | Coal | | 550 |
| Global Energy Lima ** | OH | Coal | | 550 |
| Leucadia National | LA | Coke | | 430 |
| Madison Power | IL | Coal | | 500 |
| Mohave Generating Station | CA | Coal | | 900-1,000 |
| Mountain Energy | ID | Coal | | 500 |
| Orlando Util./Southern | FL | Coal | | 285 |
| Power Holdings | IL | Coal | SNG | 400 (stm) |
| Rentech | WY | Coal | Diesel | 105 |
| Royster Clark/Rentech ** | IL | Coal | Polygen | 25 |
| Southeast Idaho Energy | ID | Coal | | 500 |
| Steelhead Energy ** | IL | Coal | | 545 |
| Synfuel | OK | Coal | | 600 |
| Tondu Energy | IN | Coal | | 640 |
| Xcel Energy | CO | Coal | | 150 |
| Otter Creek | MT | Coal | Diesel | 100,000 b/d |

*Source: Gasification Technologies Council*

* Note: Plant size reported as MWe in electrical output equivalent (unless otherwise noted), in contrast to size units of $MW_{th}$ syngas used throughout this document.
** Marked projects have been included in the database reported and the text of this document. They are listed here because they were previously of unspecified size or the size has changed.

The survey that is the basis for this brochure was conducted by Childress Associates and involved all major gasification technology vendors, suppliers of supporting technologies, and owners/operators of gasification-based power and manufacturing plants. The associated database derived from the survey is available at the DOE NETL website:

**www.netl.doe.gov/coal/gasification/index.html**

The database is available in several formats:

- A Microsoft Excel® spreadsheet containing all data fields for all records contained in the original Microsoft Access database.
- An Adobe® PDF file that is bookmarked for sections sorted by technology vendor, feedstock, country, region, and product.
- A Microsoft Access® database file that allows searches for records by the following criteria: plant ID number, region, country, year of startup, gasification technology, main feed(s), plant capacity, and main products.

This searchable database is also available on the website of the Gasification Technologies Council.

## Acknowledgments

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