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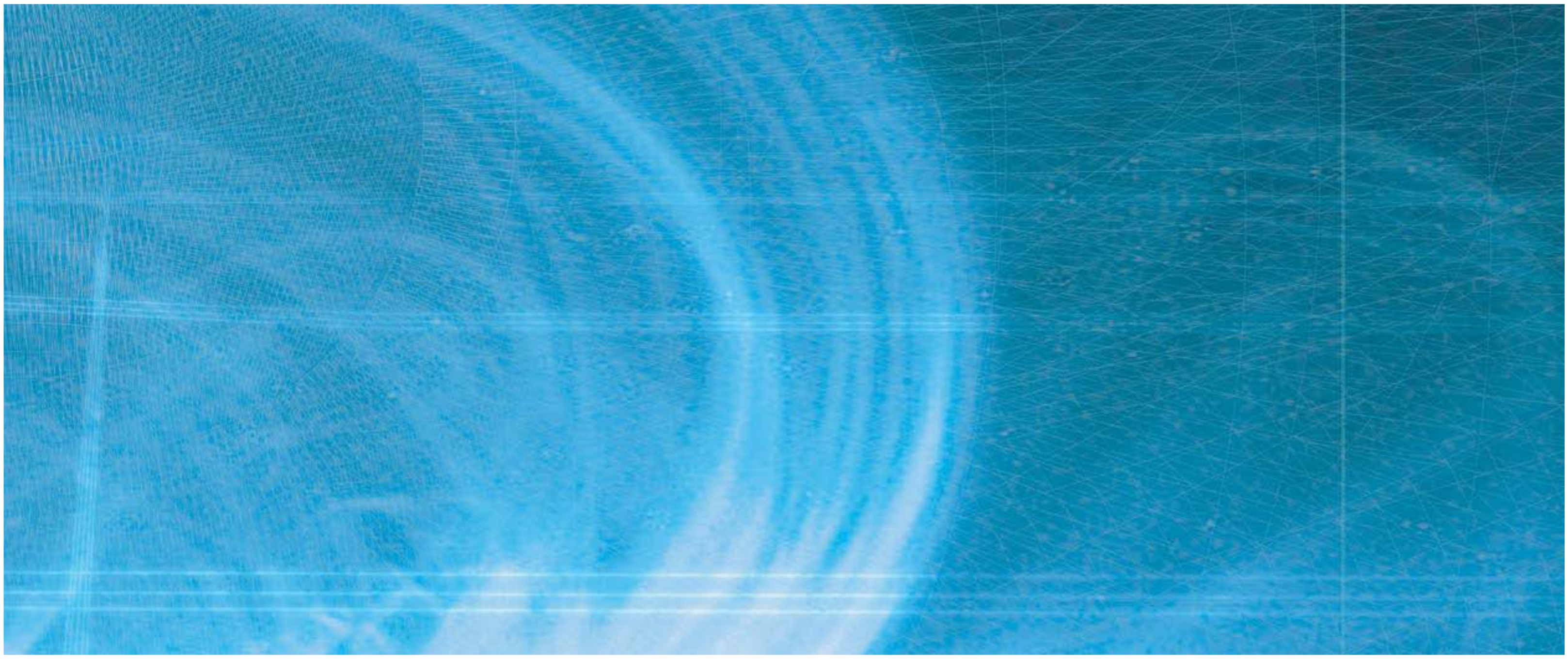
# Coal-Based Integrated Coal Gasification Combined Cycle: Market Penetration Recommendations and Strategies

Produced for the Department of Energy (DOE)/ National Energy Technology Laboratory (NETL) and the Gasification Technologies Council (GTC)



September 2004

# Coal-Based Integrated Gasification Combined Cycle: Market Penetration Strategies and Recommendations

## Final Report

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# DISCLAIMER



For accurate assessment of figures, this document should be viewed or printed in color.

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# Executive Summary

Can integrated gasification combined cycle (IGCC) technology play a major role in our nation's energy future? The promise of coal-based IGCC technology has been around for decades. In that time, only two power plants employing this technology have been constructed in the U.S. However, our nation's energy industry is undergoing immense changes, making the time ripe for investors to consider IGCC.

Given the need for further U.S. energy independence and the importance to the nation's economy of competitively priced electrical power, coal must continue to play a prominent role in the U.S. power generation portfolio. Environmental regulations and societal expectations require extremely high environmental performance of our coal-based power generation facilities. IGCC is able to meet these requirements and is a prime candidate to address intermediate term needs and anticipate future requirements.

IGCC is a power technology that generates electricity in the same manner as natural gas combined cycle (NGCC). A gasifier transforms the coal into a synthesis gas (syngas). After several stages of cleanup, the syngas is combusted in a gas turbine to produce power and excess heat. The heat is used to generate steam for driving the steam turbine.

Conditions are ripe for investors to consider how IGCC technology can play a major role in the energy future of the U.S.

This coal-based IGCC Technology Study utilized:

- The opinion of and data from industry experts
- Detailed economic and financial modeling including the EIA's NEMS and a new power pricing model
- State Public Utility Commission decisions related to IGCC technology
- Publicly available corporate information

This study looks at the market potential for the use of a typical coal-based IGCC technology in the U.S. from 2004 to 2025. It identifies a number of recommendations designed to enhance IGCC market penetration opportunities given the uncertainties of the future. The study is based upon the latest views and data from experts in the industry, as well as detailed economic and financial modeling and analyses of recent relevant investment decisions. Scenarios representing a range of possible futures are assessed using the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS). The financial impacts of future technology improvements are further refined using a power pricing model specifically developed for this study. This study examines IGCC-related decisions by the State Public Utility Commissions, as well as publicly available corporate information to identify the role non-Return on Investment (ROI) considerations have had on the IGCC related investment actions. All of this information supports the identification and assessment of a number of market entry options and recommendations for both near-term market entry and longer-term market sustainability.

## Looking into the future

The capital investment required to use IGCC is substantial and demands strong insight into the conditions that the industry will be facing in the future. There are significant uncertainties that are considered in this study because they could have a major affect on future investment decisions. A few of the most significant of these uncertainties include:

- Will the demand for electricity continue to be strong and at what price?
- Will the environmental regulatory framework under which the power industry operates change and if so, how?
- What technological advances can we expect in both IGCC and the power industry's technology alternatives?
- What is the future for natural gas (NG) prices?
- What are the market place's perceptions and investment expectations and can IGCC overcome these perceptions and fulfill expectations?

### *Will the demand for electricity continue to be strong and at what price? Will the environmental regulatory framework for the power industry change and if so, how?*

Considered future environmental regulatory scenarios:

- Current Regulatory Framework
- Multi-Pollutant Regulation
- Multi-Pollutant Plus Carbon Regulation

Future electricity demand and price forecasts are influenced greatly by the future environmental regulatory framework under which the U.S. power industry would be operating. The U.S. has placed increasing emphasis on safeguarding the environment and has established a complex regulatory framework to address the major emissions from the power sector. Recent public debate has focused on creating a more expansive regulatory framework to cover currently unregulated emission types in the power sector, such as mercury and carbon, along with more restrictive limits on existing regulated emissions, such as nitrogen oxide ($NO_x$) and sulfur dioxide ($SO_2$). Whether such changes will occur by 2025 and the critical elements of those possible changes are significant unknowns.

To assess the potential for IGCC market penetration in a range of potential regulatory futures, three scenarios, representing increasingly restrictive environmental constraints, are assessed in this study. The *Current Regulatory Framework* scenario represents a future where emission regulation is essentially similar to that in effect today. In the *Multi-Pollutant Regulation* scenario, the regulatory structure includes significantly reduced $NO_x$ and $SO_2$ emission levels and new caps for mercury. The $NO_x$ and $SO_2$ requirements modeled closely resemble those in the Clear Skies Act of 2003 (H.R. 999/S. 485), while the mercury caps more closely resemble those previously under consideration by the Environmental Protection Agency (EPA) for their Maximum Achievable Control Technology (MACT) standard. In the *Multi-Pollutant Plus Carbon Regulation* scenario, a carbon constraint on the electricity sector is added to the previous scenario. The carbon constraint modeled closely resembles that included in the Climate Stewardship Act of 2003 (S. 139). These three scenarios provide the basis for assessing IGCC's market penetration potential under a range of environmental constraints.

### *What technological advances can we expect in both IGCC technology and the power industry's technology alternatives?*

Considered technology scenarios:

- Moderate Technology Progression
- Advanced Technology Progression

Major research and development (R&D) efforts are in the planning stages or underway for many power generation technologies, including IGCC. Advances in these technologies can significantly affect the choices made by power producers in the future as they plan for future demand. Although R&D success cannot always be predicted, one certainty is that the technology of the future will differ from that of today. Therefore, this study does not consider technological stagnation as an option. The *Moderate Technology Progression* scenario considers the natural evolution of all energy generating technologies, based on cost and efficiency improvements that are gradual and consistent with historical trends. A more aggressive pace of technology advance, based on the successful achievement and deployment of current and ongoing Federal R&D goals, is assessed in the *Advanced Technology Progression* scenario. Under this scenario, technology advances are not deployed instantaneously and not all advances have equal impact on IGCC competitiveness. Specific technological advances are identified to increase IGCC market penetration and to affect the timing of that entry.

### *What is the future for natural gas prices?*

Considered natural gas price scenarios (Constant 2003 Dollars):

- Base Natural Gas Price
- High Natural Gas Price

The future of natural gas prices is paramount in the potential for IGCC market penetration. Over the past decade, natural gas has become the preferred technology for power producers. However, the recent rise in natural gas prices in the U.S. market has partially offset the comparatively low capital investment, allowing entry for other fuels.[1] Given the significance of natural

[1] The historic price volatility of natural gas and other considerations also play a significant role in weakening the competitive position of natural gas. This study was conducted in constant dollars reflecting fundamental values of commodities. We report gas price trends in constant 2003 dollars; actual prices would differ from these by the effects of inflation.

gas prices on IGCC market penetration, this study examines two potential price scenarios. The Base Natural Gas Price scenario closely resembles the EIA's Annual Energy Outlook for 2004 (AEO2004). That analysis presents a slight rise in natural gas prices continuing from now until 2025. A more significant price increase for the same period is assessed in the High Natural Gas Price scenario. This scenario examines the effect of prices that follow the mid-December 2003 futures curve for natural gas until 2009 and from then is straight-lined to the 2025 National Petroleum Council's (NPC) reactive natural gas price endpoint.

*What are the market place's perceptions and investment expectations, and can policy incentives help IGCC overcome any negative perceptions and fulfill the investor expectations?*

The public debate on energy has considered power generation-side policy incentives designed to accelerate the introduction of new technologies and to increase the utilization of existing technologies. These incentives can include direct subsidy, financial guarantees, and tax changes that affect a technology's capital and/or operating costs. This study assesses the potential for near-term policy incentives related to penetration of IGCC and its competitors by simulating the generation-side incentives discussed in House Report 108-375, the conference report of the Energy Policy Act of 2003 (H.R. 6).

The market place's perceptions and investment expectations do not always result in strict application of ROI and other similar financial analyses. Rather, uncertainties, perceptions, and other considerations are factors to a greater or lesser extent in a given investment decision. Uncertainty and perceptions are particularly significant to the consideration of IGCC, where decisions will be made based upon limited experience. These concerns are likely to diminish with the construction and operation of additional domestic facilities. Other considerations, such as impacts on environment and local economy, the local cost of electricity (COE), and resource proximity, are particularly significant in electricity generation decisions where markets are not fully deregulated and governmental bodies play a stronger role in the investment decision. This study evaluates recent IGCC-related investment actions and finds that these non-ROI factors have played significant roles. Some of these non-ROI factors are beneficial to IGCC, while others are not. However, whether most factors are considered beneficial is dependent on the circumstances for which the action is under consideration. Locational targeting of initial IGCC proposals should increase favorable outcomes.

## Key Findings

The key findings draw from the study's analysis of the environmental, technology, natural gas, and policy scenarios. The study examined these scenarios to understand how possible futures will affect IGCC and competitor technologies and provided a means for developing IGCC market penetration recommendations. In no way does the analysis intend to promote one direction over another or encompass all of the intricacies of future scenarios.

*1) IGCC captures a significant market share under a variety of regulatory and environmental scenarios considered in this study due to its favorable environmental characteristics.*

Figure ES-1 summarizes the scenarios under which IGCC, under its own merits and without any government subsidies, captures a significant market share. The cumulative additions shown are counted from the date of initial operation, not from the date of initial construction. The three environmental regulatory scenarios described below were considered along with the Moderate Technology Progression and Base Natural Gas Price scenarios.

In the Current Regulatory Framework scenario, IGCC is projected to enter the market in 2010 and achieve 34 gigawatts (GW) of cumulative capacity or 12 percent of total new capacity addition market share by 2025. These additions would come primarily at the expense of pulverized coal (PC) combustion due to more technology advancements in IGCC. In addition, IGCC has a small operating cost advantage with respect to $SO_2$ and $NO_x$ that becomes important as standards become more restrictive in later years.

Of the three environmental regulatory scenarios, IGCC performs the best in the Multi-Pollutant Regulation scenario, under which it is projected to develop 74 GW of cumulative capacity or 25 percent of total new capacity addition market share by 2025, preserving a strong role for coal in the power sector of the future. This results from IGCC's significant capital cost advantages in meeting mercury constraints as compared to PC. The cost of additional $NO_x$ controls, however, reduces the market penetration of coal-based technologies, signaling the need for further R&D in that area.

A Multi-Pollutant Plus Carbon Regulation scenario appears to be somewhat more favorable to IGCC market penetration than the Current Regulatory Framework. IGCC gains 41 GW by 2025, or 14% of the new capacity addition market share. However, it is not the addition of carbon constraints that slightly improve IGCC's market potential over the Current Regulatory Framework scenario; instead, it is the significant influence of mercury constraints from the Multi-Pollutant Regulation scenario. The mercury constraints provide IGCC with a market penetration boost that is almost completely undone by carbon regulation in the Multi-Pollutant Plus Carbon Regulation scenario.

*2) Successful R&D leading to advances in technology have the most dramatic impact on IGCC's market penetration potential.*

The three environmental regulatory scenarios described below were considered along with Advanced Technology Progression and Base Natural Gas Price scenarios (see Figure ES-2).

Under the more aggressive, advanced technology scenario, IGCC not only realizes the improvements assumed in the moderate technology scenario, but also in government R&D areas such as:

- Warm gas cleanup, which improves efficiency and lowers capital and operating costs;
- High-temperature mercury control, which improves efficiency;
- Fuel cells, which significantly improves efficiency by making fuel cells the primary power driver; and
- Membrane separation technologies, which advance at a faster pace.

These R&D advances make IGCC the predominant coal technology under the Current Regulatory Framework scenario. With these projected technological advances, IGCC is projected to increase its cumulative capacity by 2025 to 89 GW or 27 percent of total new capacity addition market share, 55 GW more than projected in the moderate technology progression scenario.

IGCC again is projected to achieve maximum market penetration under the Multi-Pollutant Regulation scenario. Under this scenario, IGCC gains 98 GW of cumulative capacity or 32 percent of total new cumulative capacity additions by 2025, up from the 74 GW projected in the moderate technology progression scenario. Improved efficiencies realized under the Advanced Technology Progression scenario benefit all fossil technologies.

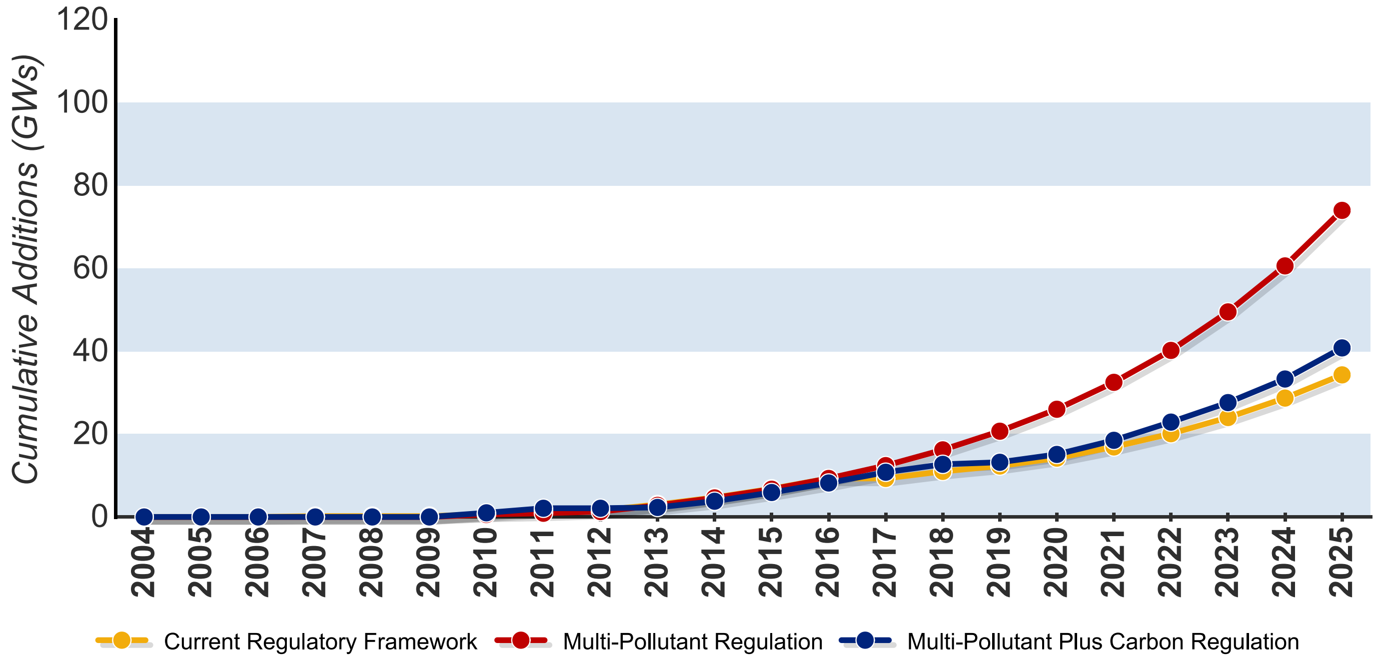


Figure ES-1: IGCC Additions for Different Environmental Scenarios Under Moderate Technology Progression with Base Natural Gas Prices

Aggressive advances in IGCC technology allow coal to thrive under Multi-Pollutant Plus Carbon Regulation. In this scenario, IGCC becomes more competitive with natural gas technologies by adding a total of 80 GW of cumulative capacity or 29 percent of capacity additions by 2025. Natural gas technologies add 165 GW of capacity additions or 59 percent of new cumulative capacity additions by 2025.

### *3) Coal regains market share with high natural gas prices.*

Even though NGCC and other natural gas technologies have a fairly large advantage with regard to capital cost and is the dominant technology in most scenarios, non-gas technologies penetrate the market place when NGCC fuel costs are high relative to its competitors. Fuel costs represent the principal component of operating cost and, hence, are a major determinant in IGCC market penetration. Unlike coal, natural gas prices have been extremely volatile in recent years and have been projected with much uncertainty as well. The study examined the three environmental regulatory scenarios with moderate technology progression and high natural gas prices. Figure ES-3 summarizes these scenarios.

Under the Current Regulatory Framework, coal technologies are projected to overtake natural gas as the principal fuel choice, with PC becoming the dominant technology. IGCC is projected to enter the market in 2010 and add 67 GW of cumulative capacity or 22 percent of total new capacity addition market share by 2025, compared with 34 GW in the Base Natural Gas Price scenario. With advances in technology, cost reduction through R&D, IGCC could attain even more market share in the high natural gas price scenarios.

High natural gas prices would intensify competition between IGCC and natural gas technologies under the Multi-Pollutant Regulation scenario. IGCC is projected to continue to be the dominant coal technology in a multi-pollutant regime; however, added costs of $NO_x$ emission controls for IGCC allow natural gas technologies to maintain their market share lead. In total, IGCC would enter the market in 2009 and would add 109 GW of cumulative capacity or 35 percent of total new capacity addition market share by 2025, compared with 74 GW in the Base Natural Gas Price scenario.

In a High Natural Gas Price and Multi-Pollutant Plus Carbon Regulation scenario, IGCC enters the market in 2010, and gains 86 GW in cumulative capacity by 2025 or 30 percent of total new cumulative capacity additions. This is a 45 GW increase in cumulative capacity additions as compared with the Base Natural Gas Price scenario. If the High Natural Gas Price scenario were to become the future, then IGCC would attain 98 percent of new coal generation capacity additions. IGCC would also remain the chief competitor to natural gas technologies. In all carbon-constrained scenarios,

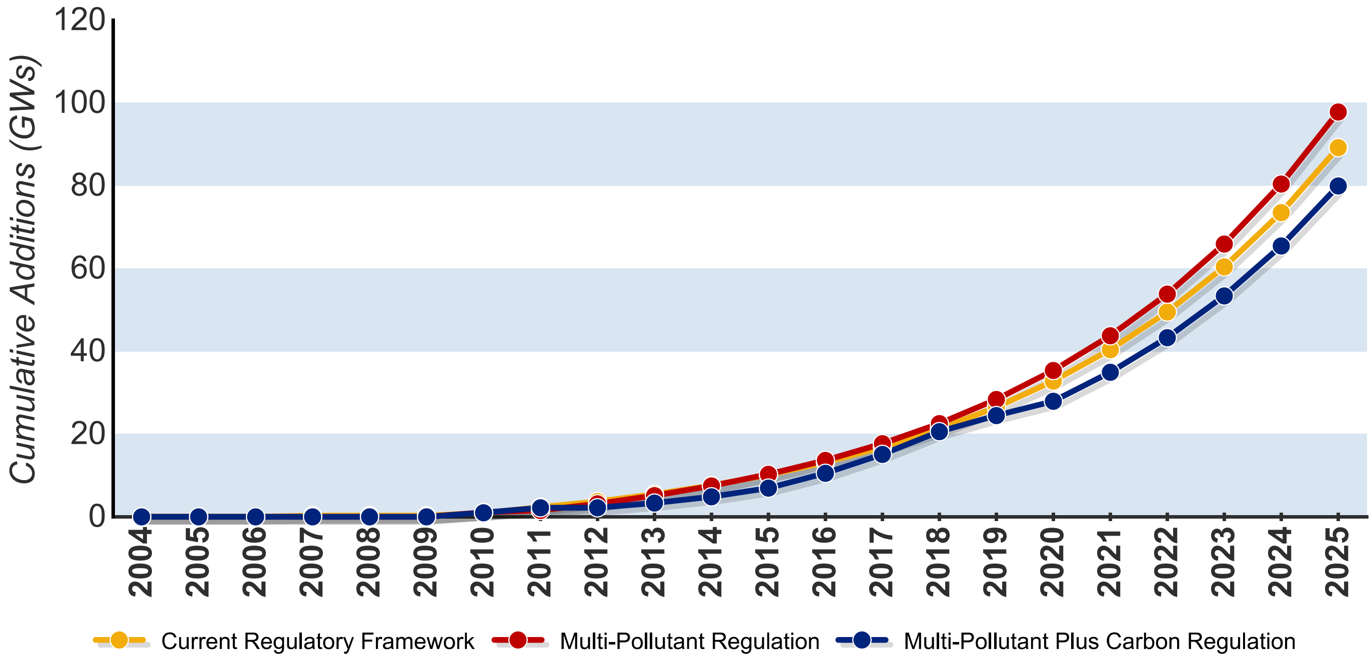


Figure ES-2: IGCC Additions for Different Environmental Scenarios
Under Advanced Technology Progression with Base Natural Gas Prices

IGCC and natural gas technologies generally elected to pay carbon allowances instead of using costly carbon capture technologies.

### *4) Policy incentives could play a role in moving forward IGCC market entry.*

The impacts of the power generation-side policy incentives are described below for the Current Regulatory Framework and the Multi-Pollutant Regulation scenarios. To model this scenario, power generation incentives similar to those discussed in the conference report of the Energy Policy Act of 2003 (H.R. 6) were developed. For each policy incentive scenario, the study assumed Moderate Technology Progression with Base Natural Gas Prices. Figure ES-4 illustrates the impact of these scenarios on IGCC.

In the Current Regulatory Framework scenario, policy incentives are projected to move IGCC's market penetration date ahead by two years, from 2010 in the base case scenario to 2008 in the policy incentive scenario. In addition, IGCC attains 51 GW or 17 percent share of total new capacity additions by 2025, some 17 GW more than would be added without the policy incentives. The policy incentives positively impact coal technologies by lowering the risk of investment through loan guarantees and by providing tax incentives, which lower the annual operating costs. This makes coal more competitive by countering a barrier to market penetration (capital costs) and emphasizing its strength (low operating costs). The policy incentives also open opportunities for advanced coal technologies in re-powering existing coal plants.

The policy incentives under Multi-Pollutant Regulation would increase IGCC's market penetration date to 2007, which is three years sooner than the base case Multi-Pollutant scenario with no incentives. This early penetration date was accomplished because the modeling was performed in 2003 and assumed a four year construction timeline. Under this scenario, IGCC becomes the dominant coal technology, attaining an 85 percent share of the coal market. PC is projected to add 16 GW of cumulative capacity in this scenario, but most of this is earmarked in the incentives package modeled as "repowerings." Total IGCC additions would be 93 GW, 19 GW more than the base scenario with no policy incentives. IGCC represents 31 percent of the total new capacity additions by 2025. Figure ES-4 summarizes the results of the simulated policy incentives for the Current Regulatory Framework and the Multi-Pollutant Regulation scenarios.

### *5) Investor uncertainties can hinder IGCC market penetration.*

With few coal-fired gasification plants producing power in this country, investor uncertainties can dominate decision-making. Some of the most significant uncertainties include:

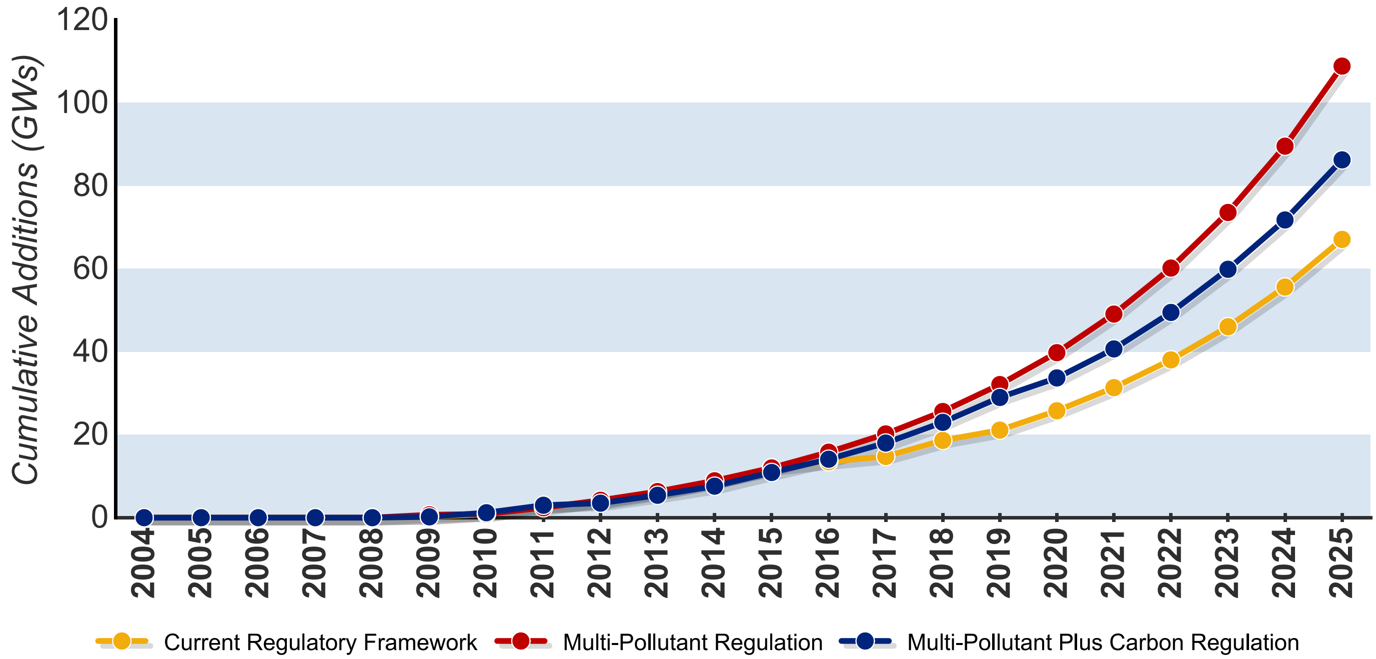


Figure ES-3: IGCC Additions for Different Environmental Scenarios
Under Moderate Technology Progression with High Natural Gas Prices

- Lack of standard plant design;
- Obtaining performance guarantees or wraps from engineering, procurement, and construction (EPC) firms or other technology suppliers that satisfy the risk-reward ratio;
- Availability of transmission capacity, electricity interconnects, and fuel transportation in relation to plant siting; and
- Ability to obtain power-purchasing agreements.

### *6) At the state and local levels, a multitude of other considerations can be raised that can complicate the IGCC-related investment action.*

These issues, as noted below, can carry significant weight particularly in states that have not fully deregulated the electric power industry:

- COE
- Reliability of generation assets
- Use of local fuel and water resources
- Fuel diversity, transmission capacity
- Air, water, and landfill impacts
- Land use, noise, and not-in-my-backyard (NIMBY) concerns

State and local considerations further complicate these issues as priorities are applied differently. As the qualitative analysis in Chapter 7 notes, recent IGCC initiatives have faced regulatory hurdles, as interested parties did not have the necessary understanding of state and local issues prior to pushing forward an investment decision.

### *7) Of all the market characteristics, the barriers to market entry represent the largest hurdle for IGCC's market penetration.*

The barriers to market entry for IGCC include the capital costs needed for an IGCC plant, sensitivities on coal's environmental cleanliness, and perceptions that IGCC technologies are still in an R&D mode. In addition, internal competition is intense among fossil technologies. In the current market of higher natural gas prices, IGCC, PC, and NGCC all appear to be viable candidates. Buyers or electricity purchasing entities have strong purchasing power in the near-term as electricity prices have dropped considerably from a few years ago. On the other hand, suppliers, including the numerous technology providers and EPCs, generally exhibit weak pricing power. The financial markets represent the one exception to suppliers. The markets have strong power in limiting investments because they are averse to funding new generation projects while they hold bankrupted generation assets on their books.

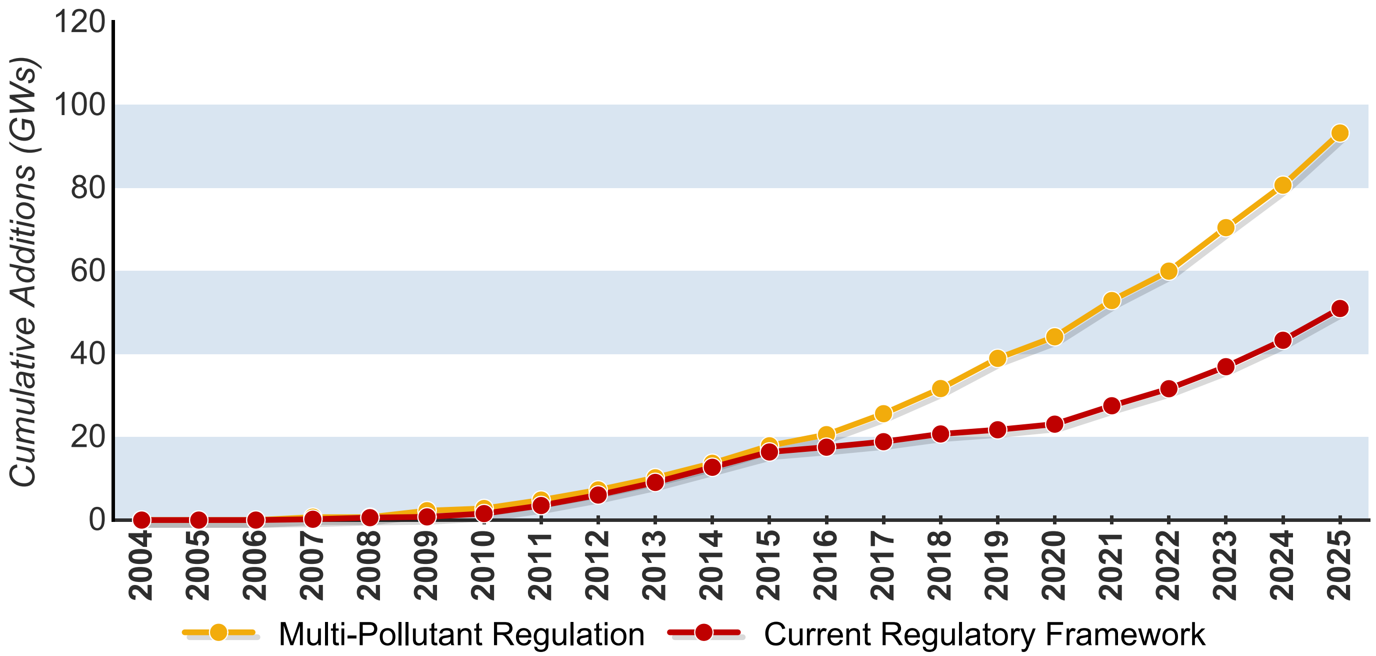


Figure ES-4: IGCC Additions for Different Environmental Scenarios
Under Moderate Technology Progression with Base Natural Gas Prices and Federal Policy Initiatives

*8) Refueling existing NGCC assets with coal gasification, polygeneration of chemicals or fuels with power production, and repowering old PC facilities appear to have the most potential in the short-term.*

Refueling idle or bankrupted NGCC assets is the most appealing option from a cost and financial risk analysis perspective. If located in areas favorable to coal technologies, bankrupted or idle NGCC assets can be purchased at a discount and refueled with coal gasification. The next best option could be a polygeneration site. Polygeneration is the co-production of electricity and chemicals, fertilizers, and/or transportation fuels from coal-derived syngas. While not within the scope of the project, polygeneration offers flexibility in products that could be attractive to integrated power and chemical manufacturers. Finally, this study found that repowering brownfield PC plants with coal gasification represents a small, yet possible market entry strategy within a more intensely regulated future. The repowering option could factor more heavily in states that have old PC facilities and stricter air emission standards than Federal regulations.

## Recommendations

This study identifies a number of recommendations that can assist in IGCC market penetration in all scenarios. These recommendations are organized around the three overriding challenges:

- Overcoming financial hurdles relative to competing technologies,
- Managing investment uncertainty, and
- Mitigating siting risks.

### Overcoming IGCC's financial hurdles

Overcoming IGCC's perceived and actual financial burdens relative to competing technologies will require a combination of technology improvements and market entry strategies.

*1) From the technology side, approaching R&D from both a short and long-term perspective would help with both earlier penetration and overall capacity additions.*

Technology advancements that increase IGCC availability and decrease capital costs will have a greater economic impact than improvements in operating costs and efficiencies. Short-term R&D efforts, therefore, should focus on eliminating the need for a spare gasifier, standardizing plant design, and/or lowering the cost of $NO_x$ reduction technologies. These efforts would help early penetration of IGCC technologies. A long-term R&D approach would focus more on continuing to expand IGCC's overall market penetration through capacity additions. Particular long-term R&D efforts would include:

- Integrating and optimizing FB, G, and H frame turbines on synthesis gas (syngas);
- Achieving warm-gas cleanup;
- Replacing cryogenic air separation units (ASUs) with membrane separation technologies;
- Developing low-cost, highly efficient, and scalable fuel cell technologies; and
- Lowering the cost of carbon controls as a hedge against the possibility of a multi-pollutant future with carbon regulation.

*2) Selecting the appropriate market strategy would significantly lower the costs of entering the market.*

Costs associated with IGCC entering the market could be significantly lowered by selecting the appropriate market strategy. For example, refueling could be effective in reducing a large portion of the capital-cost. Bankrupted assets held by large banks would be ideal as long as the asset is situated in an area applicable to coal power.

## Managing investment uncertainty

### *3) Polygeneration's potential to further coal gasification justifies a more in-depth assessment of this approach.*

Polygeneration could be utilized to reduce capital cost uncertainties by acting as a hedging mechanism against price changes. A polygeneration site could produce power and other products, such as chemicals, fuels, and fertilizers, which could be varied in ratio depending on the market price and plant turndown ratio. In addition, polygeneration could provide energy storage potential as plants produce electricity at peak demands and store synthetic fuel or other products at off-peak times. The downside in IGCC polygeneration is the added complexity of integrating a power facility with a chemical facility. Chemical firms, however, may consider addressing this complexity as natural gas prices continue to rise and chemical facilities begin to examine coal gasification as a viable alternative.

### *4) Options should be explored for developing a limited program of loan guarantees at the Federal government level to facilitate a sufficient number of IGCC plants to emerge.*

Uncertainty in capital costs has made obtaining performance guarantees, or wraps, difficult for IGCC investors. IGCC represents a way to maintain coal as a viable fuel source under a wide range of environmental restrictions. As an abundant, domestic fuel source, coal plays a critical role in meeting our energy security and fuel diversity goals. The NEMS based analysis demonstrated that such policy incentives can shorten the time for new IGCC capacity, and the qualitative analysis notes that loan guarantees would help mitigate capital cost uncertainties by lowering the cost of capital.

## Mitigating siting risks

### *5) Targeting regions for initial market entry where IGCC's advantages are relevant will be key to successful market penetration.*

Investor savvy should play a significant role in mitigating siting risks by targeting regions for initial market entry. Regions that match well with IGCC's advantages include those with some degree of regulation or public power, a strong need for more jobs, limited fuel diversity, high or volatile natural gas prices to utilities, and coal generation capabilities that are at or approaching non-compliance for National Ambient Air Quality Standards (NAAQS).

### *6) Additional studies assessing IGCC's applicability to water-constrained areas should be explored.*

A particular advantage to IGCC is its lower water requirements compared with PC and other energy sources. Competition for available water is growing to a point where a number of power project proposals already have been impacted. Given the large amount of additional capacity projected in all scenarios to meet projected demand, this issue will likely rise in significance during the time period studied.

### *7) The technology needs a strategic communications plan to ensure the public has an accurate understanding of the technology and its potential.*

Public perceptions about IGCC vary significantly. Even Public Utilities Commission (PUC) staff has significant misconceptions about the technology's reliability and advancement. Public perceptions of the technology will represent an increasing obstacle to siting IGCC. Continuing and expanding the communication of IGCC's benefits to regulators, environmentalists and siting authorities, particularly emphasizing that IGCC produces a clean gas for combustion instead of using coal directly, may aid in shifting public perception positively towards IGCC.

### *8) One goal of a strategic communication plan is to establish a common understanding of priorities between buyers and sellers.*

The strategic communication plan should facilitate a common understanding of proprieties between buyers and sellers. The study, in its limited application, found differences among the industry representing buyers versus sellers concerning the relative importance of a number of key criteria. The perceptions issues surrounding IGCC suggest better communications are needed between IGCC proponents and their potential customers.

*9) Federal and state regulators may need to take steps to develop a consistent set of standards for siting and permitting IGCC plants.*

The sheer number and variety of siting issues that can be a component of decision-making can create significant delays in approving and permitting an IGCC plant. These delays could continue to push back market entry for the technology. As an undeveloped and complex technology, the permitting process can be extensive and contradictory. For example, although some states are considering coal gasification as the Best Available Control Technology (BACT) for coal fueled power generation, others are holding it to the same standards as natural gas plants.

## Conclusion

This report has analyzed IGCC's potential market penetration under different environmental, technology, natural gas price, and policy incentive scenarios. In each scenario, the study identified key findings that highlight IGCC's advantages and challenges. These findings showed that IGCC is applicable in many future scenarios. Nonetheless, the adoption of IGCC and the magnitude of its impact ultimately will depend on the strategies employed for overcoming capital costs, investment uncertainty, and siting risks. The recommendations offer solutions for moving these obstacles aside and allowing IGCC to penetrate the market place. While the Nation's energy future may be uncertain, it can be lit in part by IGCC – a clean, reliable, and economic technology that uses our nation's abundant and affordable coal resources.

IGCC can provide the Nation with a clean, reliable, domestic source of energy at an acceptable economic and environmental cost.

# Chapter One: Purpose and Scope of the Study

The U.S Department of Energy/National Energy Technology Laboratory (DOE/NETL) in partnership with the Gasification Technologies Council (GTC) requested a study that explores the opportunities for gasification technologies for 20 years into each of at least three different environmental scenarios. This study would provide a basis for understanding the changing driving forces in coal and power industries with associated risks and implications, and how these energy market dynamics might impact gasification technologies. The following sections provide an overview of the project, a description of integrated gasification combined cycle, and a description of the industry.

## 1.1. Purpose of the Study

Rising natural gas prices and a desire for fuel diversification represent some of the reasons why power developers are reexamining their power generation portfolios. As a result, more inquiry recently has gone to clean-coal technologies to alleviate these concerns. A particular clean-coal technology, integrated gasification combined cycle or IGCC, has been moved to the forefront of coal-based technology choices. IGCC, in its simplest form, is a technology that converts coal to synthesis gas or syngas for combustion in a gas turbine. IGCC's benefits lie in its resemblance to natural gas combined cycle (NGCC) in that it has very low emissions and uses mature combined cycle technology. IGCC has an advantage over NGCC in its much lower operating costs, similar to pulverized coal (PC).

This study's purpose is to assess ways for increasing coal-based IGCC's market penetration potential within the United States from now until 2025 by weighing its benefits and challenges. The study examined IGCC, both quantitatively and qualitatively, under a range of future scenarios that were determined to either help or hinder the technology's growth. These scenarios included sensitivities related to environmental constraints, technology advancements, natural gas (NG) prices, and policy incentives.

The products of this study are technology, policy, and economic recommendations for furthering IGCC's market penetration within the various scenarios (see Chapter 9). The technology recommendations will result in providing federal and private research with a roadmap for making IGCC more competitive. The policy recommendations identify opportunities to increase IGCC market penetration under a range of legislative and regulatory scenarios that IGCC increases its presence. Finally, the economic recommendations assess the quantitative and, as importantly, the qualitative factors for improving investor interest in this technology. The net effect of this study is to help technology suppliers, buyers, investors, and regulators better understand the market forces in the coal and power industries, associated risks and critical barriers, and the requirements needed for successful market penetration of IGCC.

## 1.2. Scope of the Effort

The scope of this IGCC study is bounded by the industry examined, the feedstock used, and the timeline for projecting market penetration. For the industry, the study focused primarily on the U.S. domestic power production industry. Opportunities for gasification in other industries, such as the chemical, petroleum refining, liquid fuels, and gaseous fuels industries, are relevant to IGCC market penetration but are not fully explored in this study.

The study considered only coal as the feedstock. U.S. coal reserves are estimated to be at least 250 years at current consumption levels. Other fuel sources, such as waste coal, petroleum coke (petcoke), biomass, and heavy oils, can be used with IGCC technologies; however, coal represents the largest fuel source for gasification worldwide.[2]

[2] Gasification Technologies Council

Finally, the study considered coal-based IGCC's market potential from now until 2025. This end date was chosen because National Energy Modeling System (NEMS) only projects out to 2025. NEMS is a system of models of the U.S. energy economy developed by the U.S. Energy Information Administration (EIA). It is the primary quantitative tool used to generate the agency's *Annual Energy Outlook* (AEO), and it has been used to prepare many special analyses for Congress and Executive agencies. NEMS was selected as the study's simulation program because it has a rich technology and environmental structure, both of which are required to forecast IGCC's market penetration, fuel and electricity demand and prices, and emission levels and allowance prices. NEMS is not a proprietary model, so it can be, and has been, scrutinized in detail by the public. More information regarding the NEMS model can be found in Appendix C.

## 1.3. Description of IGCC

Coal-based IGCC is best described by its two main subcomponents: a gasification island and a power island as depicted in Figure 1-1. The "integrated" aspect comes from the steam and nitrogen generation in the gasification island that supplies the power island. In understanding IGCC's two subcomponents, the discussion begins with the power island because it is the most familiar to utilities and independent power producers (IPPs).

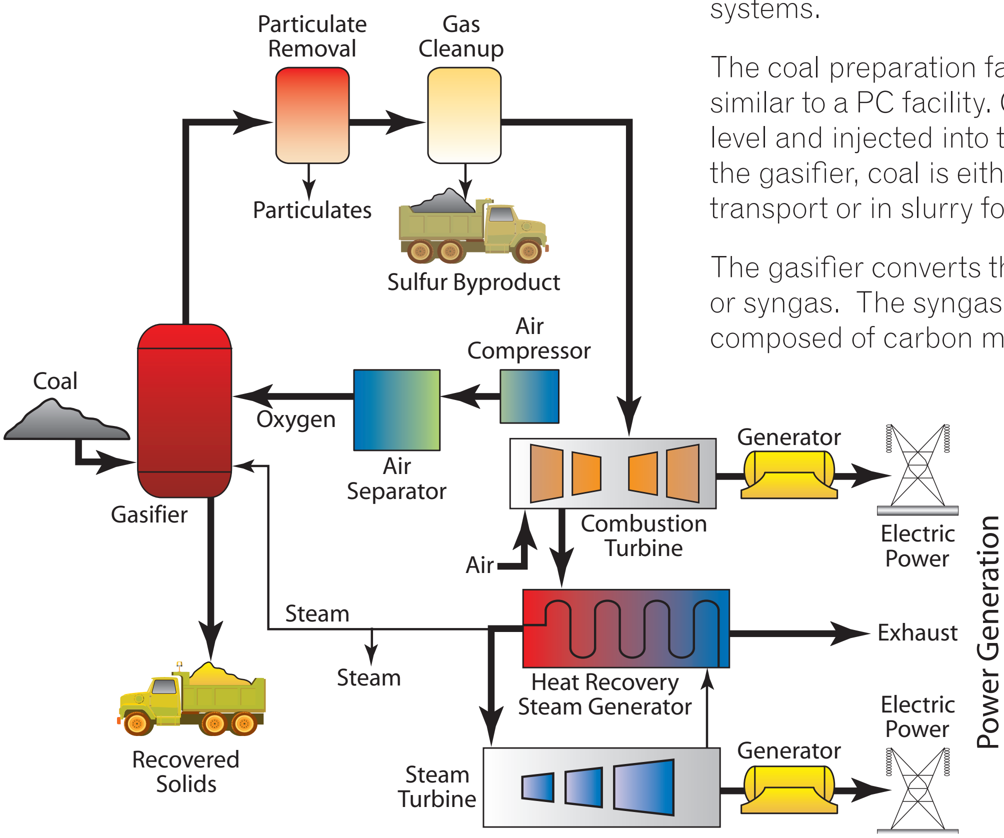


Figure 1-1: Coal-based IGCC

An IGCC power island consists of the same major elements of a NGCC plant: a gas turbine, heat recovery steam generator (HRSG), steam turbine, and condenser along with other supporting systems. These elements generate power in the same manner as a NGCC plant using the Brayton and Rankine cycles. The major difference between an IGCC and NGCC power island are the integration aspects. The IGCC power island uses excess steam from the gasification island to power the steam turbine. In addition, surplus nitrogen from the gasification island supplies the power island with nitrogen to reduce nitrogen oxide ($NO_x$) generation at the combustor.

For utilities and IPPs, the gasification island is the least familiar aspect of the IGCC plant because it more closely resembles a chemical process. The gasification island uses coal to produce a synthetic gas or syngas as fuel for the gas turbine. To make this process work, the gasification island has four main components: the coal preparation facilities, air separation unit (ASU), gasifier, and syngas cleanup systems.

The coal preparation facilities are in most regards similar to a PC facility. Coal is crushed to a very fine level and injected into the gasifier. Depending on the gasifier, coal is either fed in dry form by nitrogen transport or in slurry form by mixing with water.

The gasifier converts the coal into a synthesis gas or syngas. The syngas produced is predominately composed of carbon monoxide (CO) and hydrogen ($H_2$) and has a much lower heating value than natural gas. There are three general gasifier types: fixed-bed or moving-bed, fluidized-bed, and entrained-flow. Entrained-flow currently is the predominant technology since it appeals to the chemical and petroleum refining industries for its ratio of CO to $H_2$.[3] This

[3] Williams (222).

study assumes an average gasifier type across all three types in order not to favor any particular technology.

To make the reaction occur, the gasifier must use an oxidant. Generally, a cryogenic ASU supplies high purity oxygen needed for the reaction. In the future, lower cost and higher efficiency air separation membranes are expected to replace the cryogenic plant. Air-blown gasifiers can also provide the oxygen needed for the reaction; however, air-blown gasifiers are not considered in this study because of their limited use and success.

The syngas cleanup represents the final component of the gasification island and has four major removal steps: particulate, sulfur, mercury, and carbon removal (mercury and carbon removal are both optional processes within the current regulatory environment). The particulate removal system eliminates the charred particles in the syngas stream along with other damaging materials. The sulfur removal and recovery unit converts the sulfur compounds in the syngas stream to either sulfuric acid or pure sulfur. As for mercury removal, an inexpensive sulfur-activated carbon bed may be used to eliminate the mercury from the syngas stream. Finally, the carbon removal process involves a shift-reaction step that converts the CO in the syngas stream to $CO_2$. The $CO_2$ is then separated and compressed. IGCC's economic advantage in its cleanup systems over competitors is that it removes pollutants prior to combustion. Post-combustion flue gas cleanup generally is more cost intensive because the pollutants are not in a concentrated, pressurized stream like syngas.

## 1.4. Description of the Industry

The IGCC industry is fragmented. Unlike the NGCC industry, no IGCC power developer currently exists. Instead, the IGCC industry is composed of technology supporters. These technology supporters include the air separation equipment technology and manufacturer firms, gasification technology suppliers, the turbine technology and equipment manufacturers, and the engineering, procurement, and construction (EPC) firms. The absence of an IGCC power developer is a major problem identified by almost all of the study's participants. Unlike the NGCC industry, in which an investor deals mainly with the turbine and EPC firms, an IGCC investor must juggle at least four constituencies, making the investment much more complex. In particular, the absence of an IGCC power developer increases the obstacles of achieving performance guarantee wraps and limiting liquidated damages.

The following paragraphs describe these four main IGCC technology supporters in the power market. As with the IGCC technology description, the easiest descriptions lay with the most familiar technology supporters: the turbine technology and equipment manufacturers. The turbine firms are the suppliers of the combined cycle technology. In terms of technology advances, these firms are interested in optimizing the combustion characteristics of syngas, lowering the syngas $NO_x$ generation at the burner tips, and increasing the market penetration of FB, G, and H frame turbines. These interests will all have a major factor on IGCC's market penetration potential by increasing efficiency and lowering emissions.

The air separation firms develop and supply the equipment for producing oxygen, which is needed for the gasification reaction inside the gasifier. Currently, the technology produces oxygen through well-established, highly reliable cryogenic technology. In the future, air separation firms are looking toward air separation membranes—ion transport membranes (ITMs) and oxygen transport membranes (OTMs)—for significant cost and efficiency savings.

The gasification technology suppliers own and supply the gasification technologies as intellectual property, but they are not manufacturers of gasifiers. Instead, they sell licenses, that is rights to use their technologies, to IGCC owners and provide process design information and operating instructions to IGCC owners and their EPC contractors. The EPC contractors take this information and use it to develop detailed plant designs, arrange for equipment to be procured/fabricated, and then construct it for the IGCC owner.

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# Chapter Two: Approach

This study adopted a systematic approach in analyzing IGCC's market potential under a variety of future scenarios. The study followed three phases of development—quantitative, qualitative, and market penetration analysis—that were refined at a series of workshops. Figure 2-1 provides an overview of this approach.

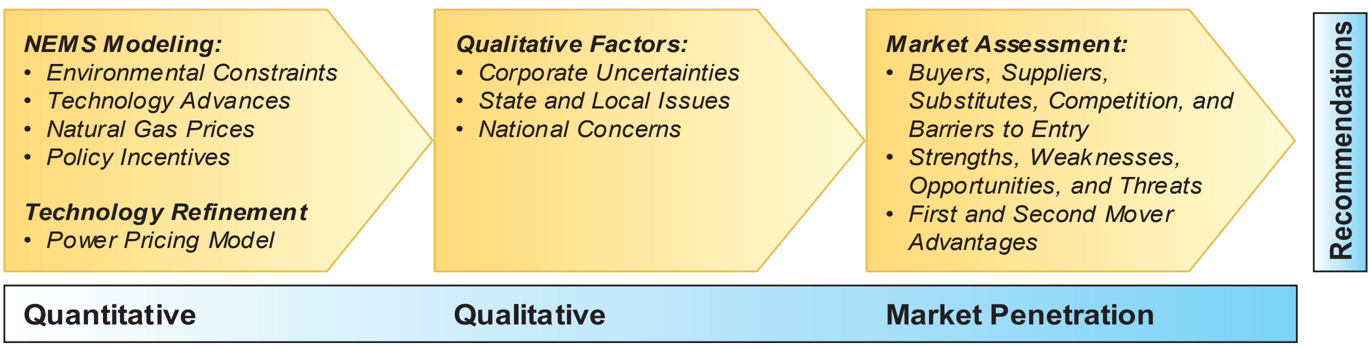


Figure 2-1: Study Approach Diagram

The quantitative phase began with a description of the scenarios and data gathering to support the designed scenarios. Describing the scenarios entailed characterizing the possible future scenarios of environmental constraints, technology advances, natural gas prices and policy incentives (Chapter 5 characterizes and describes these scenarios in detail). Once these scenarios were finalized, data were gathered through literature reviews, phone and personal interviews, formal workshops, monthly teleconferences, and formal data review and assumption meetings. The data were then assembled and modeled using NEMS to evaluate IGCC's market potential from now until 2025. The study also used a secondary analysis – the Power Pricing Model – developed by the study members to refine how technology advances would impact IGCC's economics.

After analyzing the quantitative results, the study team assessed the qualitative aspects of an IGCC investment. The qualitative analysis examined those factors that could not be modeled such as local, state, and national issues. At the local level, the study team evaluated issues such as coal perception and not-in-my-backyard (NIMBY) concerns that could limit the siting of IGCC facilities. The state-level qualitative analysis covered matters such as grid reliability, interconnects, and congestions. At the national level, discussion revolved around issues such as energy security. The purpose of the qualitative analysis was to provide additional context around the results of the quantitative results. The outcomes from the quantitative and qualitative analyses gave input into the market penetration analysis.

The market penetration analysis served as a method for pulling together the entire study's results to make business level recommendations for IGCC market penetration strategies. This analysis used classic business models to describe the attractiveness of the U.S. domestic electricity market and to evaluate the strengths, weaknesses, opportunities, and threats (SWOT) of different market penetration strategies. In addition, the market penetration analysis examined the differences between different customer types and the advantages and disadvantages of first-movers and second-movers.

In following this approach, the study team used an iterative process that depended on the feedback and refinement of inputs and assumptions from a series of workshops. This process served as a way to create an interactive dialogue between the U.S. Department of Energy (DOE)/National Energy Technology Laboratory (NETL), the Gasification Technologies Council (GTC), and Booz Allen Hamilton. This dialogue culminated approximately once every three months into four major workshops that involved at least twenty-five participants from the federal government and industry. (A timeline showing the progression of the study can be found in Appendix C.)

The four main workshops were held around the major phases of the study:

- Brainstorming (June 12, 2003): This session helped frame the context of the scenario analyses. The workshop divided the participants into four main discussion groups: Current and Advanced Technology, Legislative/Regulatory Policy, Macro/Global Economic Issues and Emissions Control, and Market Penetration/ Competitor Technologies. At the end of the session, the participants from each group presented the barriers and opportunities facing IGCC within each of the themes.
- Assessing the Scenarios (October 3–4, 2003): Building on the first workshop along with the technical data gathered through subsequent mini-workshops, phone interviews, teleconferences, and e-mails, this workshop focused on the preliminary results derived from the modeling effort and served as a forum to challenge the model inputs and assumptions. In addition, the workshop participants identified the SWOT of each of the five major market penetration strategies.
- Integration of the Refined Inputs (December 4–5, 2003): The third workshop was similar to the previous workshop in that it addressed issues related to modeling, but the third workshop addressed more refined model inputs and assumptions. This workshop also spent considerable time examining the qualitative factors affecting the investment decision.
- Soliciting Final Feedback from Buyers and Suppliers (January 29–30, 2004): At the final workshop, the main emphasis was on the qualitative factors that were impeding IGCC's development from the perspective of the technology's buyers and suppliers. The participants paid careful attention to the GTC anti-trust policy and opted not to speak if a question or scenario would have elicited competitive information.

In all four workshops, the participants closely examined how coal gasification competed against other technologies from now until 2025. In particular, the participants focused on the trigger points (e.g., the capital costs, heat rates, and the operating and maintenance (O&M) costs), "signposts" (e.g., coal technology mix), and trends (e.g., natural gas prices) in each scenario that allowed IGCC to enter the market against its competitors. Furthermore, the participants spent an increasing amount of time debating the qualitative factors (e.g., NIMBY, transmission interconnects, and coal perceptions) that could not be modeled. Together, the quantitative and qualitative aspects allowed Booz Allen to assess the IGCC market penetration strategies under the different sensitivity analyses. (Appendix C contains further details on the study's approach.)

# Chapter Three: Legislative and Regulatory Issues

One of the primary reasons this study was undertaken was a need to understand the relationship between potential legislative and regulatory changes and IGCC's market penetration. A wide range of legislative and regulatory proposals have been put forward that could significantly affect IGCC's market penetration level and rate between the present and 2025. In late 2002, the Congressional Research Service (CRS) noted,[4]

> *Currently, eight bills have been introduced in the 107th Congress to reduce emissions by increasing pollution controls on electric generating facilities.... All of the bills control at least $NO_x$ and $SO_2$; others include $CO_2$ and Hg. All of these bills involve some form of emission caps, and most include a tradable credit program to implement that cap.*

In a later report, CRS states, "The key questions are how stringent the controls will be, and whether $CO_2$ will be among the emissions subject to controls."[5]

This study examined recent legislative and regulatory proposals that may be enacted within the next few years, and used this information to create representative public-policy scenarios.[6]

The following sections provide background understanding of the legislative and regulatory issues that were assessed as part of the study.

## 3.1. Further Reductions in $NO_x$ and Sulfur Oxide ($SO_x$) Emissions

Most pending clean-air legislation contains further reductions in allowable emissions of $NO_x$ and sulfur dioxide ($SO_2$). The Clear Skies Act of 2003 (H.R. 999/ S. 485) requires a two-step reduction of $NO_x$ and $SO_2$ emissions in 2008 and 2018. It also allows for nationwide $SO_2$ permit trading, and for $NO_x$ permit trading within two regions—the Eastern and Central United States as Zone 1, the rest of the nation as Zone 2. The total $NO_x$ cap is split between these two zones. The bill also includes a "safety valve" which allows $NO_x$ and $SO_2$ allowances to be bought forward in time for a fixed cost of $4,000 per ton.

Senator Carper's Clean Air Planning Act of 2003 (S. 843) has a two-step tightening process for $NO_x$ and three steps for $SO_2$. Its $NO_x$ and $SO_2$ caps are compared with Clear Skies in Table 3-1.

Senator Jeffords' Clean Power Act of 2003 (S. 366) has a single-step cap on $NO_x$ and $SO_2$ in 2009. Its $NO_x$ cap is lower than any of the caps in the Clean

| Emission Bills | $NO_x$ | | | | $SO_2$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year and Amount (Mtons[7]) of Initial Cap | | Year and Amount (Mtons) of Final Cap | | Year and Amount (Mtons) of Initial Cap | | Year and Amount (Mtons) of 2nd Cap | | Year and Amount (Mtons) of Final Cap | |
| Clear Skies Act of 2003 (S. 485) | 2008 | 2.1* | 2018 | 1.7* | 2010 | 4.5 | N/A | N/A | 2018 | 3.0 |
| Clear Air Planning Act of 2003 (Carper, S. 843) | 2009 | 1.87 | 2013 | 1.7 | 2009 | 4.5 | 2013 | 3.5 | 2016 | 2.25 |
| Clean Power Act of 2004 (Jeffords, S. 366) | 2009 | 1.51 | N/A | N/A | 2009 | 2.25* | N/A | N/A | N/A | N/A |

Table 3-1: $NO_x$ and $SO_2$ Caps for Selected Emission Bills
*Sum of separate eastern and western regional caps

[4] Parker, L. & Blodgett, J., p. CRS–3.

[5] McCarthy, J. E., (September 4, 2003), p. CRS–5.

[6] The purpose of this legislative review is to identify areas that would warrant analysis in this report. Inclusion or exclusion from this analysis is not intended to demonstrate support or lack of support for any particular policy position.

[7] Mtons: Million tons

Skies or the Carper bills. It caps $SO_2$ emissions at the same level as the final Carper-bill cap but requires this level seven years earlier than Carper.

## 3.2. Mercury Emission Limitations

The Environmental Protection Agency (EPA) is in the process of determining a MACT level for mercury (Hg). By the terms of a 1998 settlement with the Natural Resources Defense Council[8], EPA was required to propose utility-boiler mercury MACT regulations by December 2003, finalize these regulations by December 2004, and require compliance by December 2007.

At the start of the current study, the exact MACT level had not yet been proposed. The EPA had previously used a 70 percent reduction in a cost-estimation modeling study.[9] Some other EPA-sponsored studies have used MACT reductions as low as 60 percent[10] and as much as 90 percent.[11]

Subsequent to the completion of the quantitative phase of this study, the EPA has issued a proposal for controlling mercury emissions that contains two alternative solutions.[12] The first alternative requires MACT controls to reduce emissions of mercury by 29 percent by the end of 2007. The second alternative creates a cap-and-trade program with two time-phased caps. A 2010 cap would be the "maximum reduction in Hg emissions that could be achieved through the installation of flue gas desulfurization (FGD) and selective catalytic reduction (SCR) units that will be necessary to meet the 2010 caps for $SO_2$ and $NO_x$" in another proposed rule. The 2018 Hg cap would be 15 tons nationwide, equivalent to a reduction of 70 percent of current emissions.

Reduction in mercury emissions has also been included in some of the current clean-air legislation. For example, the Clear Skies Act of 2003 requires a two-step tightening of emissions, similar to the two-step cap-and-trade proposed by EPA: a cap of 26 tons per year nationally in 2010, and 15 tons by 2018. Senator Carper's proposal also requires a two-step tightening of Hg emissions nationally but adds facility-specific requirements to emit no more than 50 percent of the Hg delivered in the fuel by 2010, and no more than 30 percent by 2018. Both Clear Skies and Carper allow Hg trading. Senator Jeffords' bill has a single national cap as well as a facility cap but no trading. Clear Skies has a safety valve for mercury, but Jeffords and Carper do not .[13] These differences are summarized in Table 3-2.

| Emission Bills | Year of Initial Cap | Initial Cap(tons) | Initial Site Requirement | Year of Final Cap | Final Cap(tons) | Final Site Requirement | Trading | Safety Valve |
|---|---|---|---|---|---|---|---|---|
| Clear Skies Act of 2003 (S. 485) | 2010 | 26 | None | 2018 | 15 | None | Yes | Yes |
| Clear Air Planning Act of 2003 (Carper, S. 843) | 2009 | 24 | Emit less than 50% of fuel's Hg | 2013 | 10 | Emit less than 70% of fuel's Hg | Yes | No |
| Clean Power Act of 2004 (Jeffords, S. 366) | 2008 | 5 | 2.48 grams per 1000 megawatt hour (MWHr) | N/A | N/A | N/A | No | No |

Table 3-2: Mercury Caps for Selected Emission Bills

8 NRDC v. EPA

9 Discussion of Multi-pollutant Strategy.

10 Jayaraman, K., Haydel, J., & Venkatesh, B.

11 Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur Dioxide, Nitrogen Oxides, Carbon Dioxide, and Mercury and a Renewable Portfolio Standard.

12 Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units.

13 Many pieces of legislation include some form of a maximum compliance costs sometimes referred to as a safety valve.

## 3.3. Restrictions on Carbon Emissions

A number of proposals would establish carbon emission restrictions. Some of the current legislative proposals set restrictions on carbon emissions in two stages. Each stage contains allowances based on a prior year's levels for covered emissions. For example, the Climate Stewardship Act of 2003 (S. 139) introduced by Senators McCain and Lieberman, has $CO_2$ emissions for the electric, industrial, and commercial sectors reduced to 2000 levels by 2009, and to 1990 levels by 2015. Senator Jeffords' proposal places a limit on $CO_2$ emissions for electric power generation in the year 2009 approximately equal to the levels produced in 1990. Senator Carper's proposal has a two tiered tightening of carbon emissions from electricity generation: by 2009 emissions should be below EIA projections for 2006, and by 2013 emissions should be below actual 2001 emissions. The Carper bill includes provisions that provide $CO_2$ allowances for renewable energy, sequestration, and other greenhouse gas (GHG) emission reductions.

One aspect of carbon emissions control is carbon storage, or sequestration. Among the current options for carbon sequestration are Enhanced Oil Recovery (EOR), Enhanced Coal Bed Methane (ECBM) recovery, storage in saline aquifers, storage in depleted oil and gas wells, and ocean disposal. Long-term research has also investigated such "environmental sinks" as forests and farmlands as a method of sequestering carbon.

Most carbon control legislation provides for emission allowances. Offsets are alternative actions that can be taken to remove carbon from the atmosphere in equal amounts to emissions from a generation facility. An example might be a reforestation program in which the carbon absorbed by the trees would equal the emissions from a power plant. The Carper bill provided for an independent review board that would authorize offset programs.

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# Chapter Four: Technology Assumptions

Assumptions concerning the pace of the technology progression were developed for IGCC and competing power generation technologies. Both a moderate and advanced technology progression scenario were developed and modeled for each technology. The moderate technology progression scenario is defined as the natural evolution of all technologies based on cost and efficiency improvements that are gradual and consistent with historical trends. Advanced technology progression, on the other hand, is based on the successful achievement and deployment of current and ongoing Federal research and development (R&D) goals. These two scenarios establish the lower and upper bounds of technology advances, with actual future being someplace in between.

The technical data assumptions, such as overnight capital costs (the capital cost of a project if it could be constructed overnight without contingency for time, risk, or government interaction through regulation); efficiencies; and O&M costs begin at the same starting point for both the moderate and advanced progression scenarios. Their 2025 endpoints differ because of aggressive technology improvements in the advanced scenarios. In all technologies, improvements over time were straight-lined from 2003 to 2025 because the timing of improvements is difficult to project. The following sections describe the assumptions considered in the modeling. Input data for these assumptions are listed and referenced in Appendix B. All costs are stated in 2003 dollars.

## 4.1. IGCC

In both the moderate and advanced technology progression scenarios, the initial IGCC plant is configured on a 550 megawatt (MW) net generation plant that initially includes two gasifiers and a spare gasifier integrated with two gas turbines and one steam turbine. The assumed lead-time for construction, testing, and initial startup is 4 years. The IGCC baseline cost and performance assumptions are shown in Table 4-1:

| Cost and Performance Metrics | IGCC (550 MW) |
|---|---|
| Overnight Capital Costs | $1400/kilowatt (kW) |
| Fixed Operating Costs | $33.8/Kilowatt-year (kW-yr) |
| Variable Operating Costs[14] | $4.0/MWhr |
| Efficiency (High Heat Value (HHV)) | 40.5% |
| Availability | 93% |
| $NO_x$ Emissions | 0.07 pounds/ million British Thermal Units (lb/MMBtu) |
| $SO_2$ Removal Rate | 99% |
| Mercury Removal Rate | 95% |

Table 4-1: IGCC Baseline Assumptions

For IGCC, moderate technology improvements assume evolutionary changes that occur at a slightly faster pace than more mature technologies such as NGCC and PC. These improvements include the following:

- Elimination of reliability and lifecycle uncertainty issues of refractory and feed injectors.
- Evolution of air separation from cryogenic separation to membrane separation, resulting in a reduction of 70 percent in air separation O&M costs, a $100/kW reduction in capital costs, and an increase of 1 percent in overall IGCC thermal efficiency. Cryogenic backup for the membrane technologies are assumed in the mid-term, but dropped by 2025.
- Modest improvement in cold gas efficiency.
- Gas turbine efficiency increase from improvements in FB, G, and H turbine technology.

[14] Variable Operating Costs for all technologies exclude fuel costs.

- Increase in steam turbine efficiency from improvements in better blading materials.

The advanced IGCC progression scenarios contain the same improvements but at a much faster pace. Additional improvements include the following:

- Membrane separation technologies arrive faster—around 2012—without cryogenic backup;
- Warm gas cleanup, which improves efficiency and lowers capital and operating costs;
- High-temperature mercury control; and
- Fuel cells replace gas turbines as the primary power driver, making the IGCC unit into an integrated gasification fuel cell (IGFC) unit.

Across the moderate and advanced scenarios, environmental legislation and regulation constraints impact IGGC and other fossil power production's costs and efficiencies. Understandably, increasing environmental controls does not affect the advanced scenarios as much in terms of added costs and lower efficiencies. In the multi-pollutant scenarios, IGCC must absorb the cost of additional $NO_x$ controls by adding a SCR in the beginning years and using low cost and higher efficient low-$NO_x$ combustor technology in the later years. The multi-pollutant plus carbon control scenarios give IGCC the option to add a shift reactor for converting the CO into $CO_2$. The $CO_2$ is then sequestered geologically. Sequestrations costs include compression and piping only up to the plant gate.[15]

## 4.2. Pulverized Coal

Coal combustion relies on supercritical pulverized coal (SCPC) technology in both the moderate and advanced progression scenarios. The study assumed a 550 MW facility and a lead-time of 4 years. The SCPC baseline cost and performance assumptions are shown in Table 4-2:

| Cost and Performance Metrics | SCPC (550 MW) |
|---|---|
| Overnight Capital Costs | $1200/kW |
| Fixed Operating Costs | $25.5/kW-yr |
| Variable Operating Costs | $6.0/MWhr |
| Efficiency (HHV) | 40.0% |
| Availability | 90% |
| $NO_x$ Emissions | 0.10 lb/MMBtu |
| $SO_2$ Removal Rate | 98% |
| Mercury Removal Rate | 50% |

Table 4-2: SCPC Baseline Assumptions

Because PC is a mature technology, and because uncertainties surround advanced alloy costs, the advanced scenarios see no significant cost improvements. In the moderate scenario, SCPC improves its efficiency from 40 percent HHV to 43.5 percent HHV by 2025, and overnight capital costs drop from $1200/kW to $1100/kW. The major difference between the moderate and advanced technology progression scenarios is that SCPC realizes a higher efficiency of 47 percent HHV by 2025.

In all three environmental scenarios, PC's $SO_2$ reduction costs are included in the cost assumptions. $NO_x$ and mercury control costs and efficiency penalties are added to the multi-pollutant scenarios. The multi-pollutant plus carbon scenarios assume SCPC must use carbon controls. Sequestration assumptions are similar to those for IGCC.

## 4.3. Natural Gas

The study modeled three different types of natural gas technologies simultaneously: a 180 MW net simple cycle, a 250 MW net combined cycle, and a 550 MW net combined cycle facility. In the moderate progression scenarios, the 180 MW simple cycle plant used one FA-frame turbine. The 250 MW combined cycle plant was modeled with an FB frame turbine, HRSG, and a steam turbine. The natural gas technologies baseline cost and performance assumptions are shown in Table 4-3:

[15] The analysis goes as far as capture and preparation costs to the fence line. Given the range of potential sequestration options, it does not include the actual sequestration costs. In practice, when considering sequestration, the modeling allowed IGCC and NGCC to choose whether to incur sequestration costs or to buy an appropriate amount of allowances. In all cases, the model chose allowances as the more economic outcome. Thus, the lack of actual sequestration costs are moot.

| Cost and Performance Metrics | Simple Cycle (180 MW) | NGCC (250 MW) | NGCC (550 MW) |
|---|---|---|---|
| Overnight Capital Costs | $350/kW | $600/kW | $550/kW |
| Fixed Operating Costs | $11.3/kW-yr | $11.3/kW-yr | $11.3/kW-yr |
| Variable Operating Costs | $1.3/MWhr | $1.3/MWhr | $1.3/MWhr |
| Efficiency (HHV) | 33.1% | 50.2% | 50.9% |
| Availability | 95% | 95% | 95% |
| $NO_x$ Emissions | 0.08 lbNOx/mmBtu | 0.02 lbNOx/mmBtu | 0.02 lbNOx/mmBtu |
| $SO_2$ Removal Rate | 100% | 100% | 100% |
| Mercury Removal Rate | 100% | 100% | 100% |

Table 4-3: Natural Gas Baseline Assumptions

The study team assumed minor improvements for both the FA and FB frame technologies over the study period in both the moderate and advanced technology progression scenarios. As for the 550 MW combined cycle facility, the improvements were modeled almost exactly the same as the IGCC power island in both the moderate and advanced progression scenarios. For example, the moderate and the advanced technology progression scenarios assumed H-frame and fuel cells as the primary technology selected by 2025, respectively.

The study did not assume any improvements needed in the multi-pollutant scenarios because natural gas is expected to be able to meet the requirements for $NO_x$, $SO_x$ and mercury. The multi-pollutant plus carbon constraint scenarios allowed a new 550 MW facility to choose between paying carbon allowances or adding carbon capture and sequestration equipment. The other two natural gas technologies displayed in Table 4-3 did not have that option. As with the coal technologies, sequestration costs include compression and piping only up to the plant gate.

## 4.4. Fuel Cells and Distributed Generation

The study modeled fuel cells as molten carbonate fuel cells with $H_2$ reformed from natural gas as the feedstock. Fuel cells by themselves were assumed to be 10 MWs in size. Starting point cost and performance data were mainly taken from the Energy Efficiency and Renewable Energy (EERE) and the National Renewable Energy Laboratory (NREL) estimates.[16] Advances in fuel cell technologies assumed for NGCC and IGCC were also applied to the 10 MW fuel cells.

Distributed generation (DG) was modeled as 1 to 2 MW microturbines. Data assumptions came from multiple sources.[17] The fuel cell and DG baseline cost and performance assumptions are shown in Table 4-4:

| Cost and Performance Metrics | Fuel Cell (10 MW) | DG Base (2 MW) | Distributed Generation Peak (1 MW) |
|---|---|---|---|
| Overnight Capital Costs | $2000/kW | $800/kW | $959/kW |
| Fixed Operating Costs | $7.5/kW-yr | $14.4/kW-yr | $14.4/kW-yr |
| Variable Operating Costs | $21.3/MWhr | $6.4/MWhr | $6.4/MWhr |
| Efficiency (HHV) | 45.5% | 32.5% | 32.5% |
| Availability | 93% | 90% | 90% |
| $NO_x$ Emissions | 0 | 0.08 lbNOx/mmBtu | 0.08 lbNOx/mmBtu |
| $SO_2$ Removal Rate | 100% | 100% | 100% |
| Mercury Removal Rate | 100% | 100% | 100% |

Table 4-4: Fuel Cell and DG Baseline Assumptions

[16] Renewable Energy Technology Characterizations

[17] Capstone Turbine Corporation Presentation; Advanced Reciprocating Engines Systems (ARES) Program

## 4.5. Non-Fossil Technologies

Non-fossil technologies include nuclear, photovoltaic, solar thermal, biomass IGCC, municipal solid waste, geothermal, wind, hydropower, and pumped storage. The cost and performance assumptions for these technologies mirror EIA's AEO2003 inputs. Technology progression for these technologies also follows the timelines and values set by EIA in the AEO2003 report.

# Chapter Five: Scenario Descriptions

The study defined four future scenarios that could impact IGCC's market penetration potential: legislative and regulatory changes, technology advances, natural gas prices, and policy incentives. The following sections characterize each of these scenarios.

## 5.1. Environmental Constraints and Technology Progression

The study analyzed three environmentally constrained scenarios – the Current Regulatory Framework continuing, Multi-Pollutant Regulations, and Multi-Pollutant Plus Carbon Regulations. In the "Current Regulatory Framework" scenario, emission regulation remains the same as prescribed by law in 2003. At the Federal level, both $SO_2$ and $NO_x$ are subject to the Clean Air Act Amendments of 1990. State emission level constraints are also included. There are no changes in emission constraints through 2025. Neither carbon nor mercury is regulated at the federal level. This scenario serves as a reference for comparison with other scenarios.

The "Multi-Pollutant Regulation" scenario represents an energy economy affected by significant emissions legislation and regulation. This scenario includes reductions in allowable $NO_x$ and $SO_2$ emission levels with trading mechanisms expanded to include $NO_x$. This scenario also includes Federal mercury emission caps. $NO_x$, and $SO_2$ emission requirements closely resemble those in the Clear Skies Initiative; mercury caps closely resemble those in earlier EPA MACT modeling scenarios. Mercury is not included in the trading regime. The policy assumptions applied in the multi-pollutant regulation scenario are:

- Reduction of $SO_2$ emissions by 73 percent, from current emissions of 11 million tons to a cap of 4.5 million tons in 2010, and 3 million tons in 2018.
- Reduction of $NO_x$ by 67 percent, from current emissions of 5 million tons to a cap of 2.1 million tons in 2008, and to 1.7 million tons in 2018.
- Mercury emissions are cut by approximately 70 percent. Emissions will be cut from current emissions of 48 tons to a cap of 15 tons in 2008.
- $NO_x$ emission caps are set to account for different air quality needs in the East and the West.
- Cap and trade provisions are included for $NO_x$ and $SO_2$.

The "Multi-Pollutant Plus Carbon Regulation" scenario represents an energy economy affected by even more stringent emissions legislation and regulation than the Multi-Pollutant scenario. It consists of the reduced $NO_x$, $SO_2$, and mercury emission limitations from the Multi-Pollutant scenario with a carbon constraint added. The constraint closely resembles that included in the McCain–Lieberman bill (S. 139).

In addition to the $NO_x$, $SO_2$, and mercury limitations from the Multi-Pollutant scenario, this scenario has a carbon cap and trade provision:

- $CO_2$ emissions are reduced in two stages.
- Stage I comes into effect in 2010 and reduces $CO_2$ to 2000 levels for the electric generating sector only. This stage will result in a reduction of about 8 percent from the levels otherwise expected in that year.
- Stage II comes into effect in 2016 and reduces $CO_2$ to 1990 levels for the electric generating sector only. This stage will result in around a 20 percent reduction in 2016 with a reduction of nearly 40 percent by 2025 from levels otherwise expected.

All three environmentally constrained scenarios were simulated within two different technology progression scenarios. The technology progression scenarios were described in Chapter 4. Table 5-1 gives an overview of the six environmentally constrained and technology progression scenarios.

| Scenario | Current Regulation | Multi-Pollutant Regulation | Multi-Pollutant Plus Carbon Regulation |
|---|---|---|---|
| Moderate Progression Technology | · Current regulatory regime<br>· Normal evolutionary technical progression | · $NO_x$ and $SO_x$ levels closely resemble Clear Skies<br>· Hg has a 70% reduction in 2008 and no trading<br>· Normal evolutionary technical progression with $NO_x$ and $SO_x$ controls | · $NO_x$, $SO_x$, and Hg constraints from Multi-Pollutant scenario<br>· Carbon closely resembles S. 139<br>· Technology from Multi-Pollutant scenario with more reliance on fuel cells |
| Advanced Progression Technology | · Current regulatory regime<br>· Technology reflects advances in Federal R&D<br>· IGCC and NGCC configuration includes fuel cells | · Same constraints as Multi-Pollution–Moderate scenario<br>· Technology reflects advances in Federal R&D<br>· IGCC and NGCC configuration includes fuel cells | · Same constraints as Multi-Pollutant Plus Carbon–Moderate scenario<br>· Technology reflects advances in Federal R&D<br>· IGCC and NGCC configuration includes fuel cells |

Table 5-1: Synopsis of Environmental and Technology Simulation Assumptions

The initial study analysis is supplemented by sensitivity analyses in which restrictions on mercury were increased beyond the 70 percent MACT, and in which the administration of carbon restrictions are changed. Chapter 6 presents a more detailed description of these sensitivity analyses.

## 5.2. Natural Gas Price Curves

Natural gas prices appear to have established a new floor price over the last year. Future natural gas prices, unlike coal prices, have a history of significant price volatility. In addition, issues such as the capability of domestic supply to meet projected demand, the potential for additional supplies from Alaska and Canada, and imports via liquefied natural gas (LNG) add to the uncertainty. As natural gas prices can significantly affect IGCC market penetration, two potential prices paths were assessed in this study. The first path, named "Base Natural Gas Prices," closely resembles the path included in EIA's AEO2004. That projection showed a slight rise in natural gas prices in real terms from now until 2025, and was used for all six of the above scenarios. The second path, named "High Natural Gas Prices," followed mid-December 2003's future's curve until 2009. From 2009 onward, the price essentially was straight-lined to the endpoint of the National Petroleum Council's (NPC's) reactive natural gas price case.[18] This endpoint was approximately $7 per MMBtu in constant 2003 dollars.

## 5.3. Policy Incentives

Of particular interest in a study of market penetration is the potential impact of policy incentives on accelerating market entry. Another means of achieving earlier market penetration is reliance on financial incentives to encourage the technology penetration. This can include direct subsidy, financial guarantees, and tax changes that affect either the front-end and/or annual operating costs. Such incentives have been discussed as part of the current energy policy debate. To assess the possible impact of policy on market entry, scenarios were developed that simulated the generation-side incentives in the conference report of the Energy Policy Act of 2003 (H.R. 6). Table 5-2 details these incentives.

[18] Shackouls, B.S.

| Section of the Conference Version of the Energy Bill | Description of the Incentives |
|---|---|
| Sec 202 Renewable Energy | Allows 60% of appropriated funds to facilities that use solar, wind, geothermal, or biomass |
| Sec 206 Grants for Biomass | NTE $20/green ton of biomass delivered; grants NTE $500K for projects |
| Sec 241 Hydro Production | 1.8 cents/kilowatt hour (kWhr) NTE $750K/year adjusted for inflation |
| Sec 401 Clean Coal Power Initiative (CCPI) | Authorizes $200M per year from 2004-2012, requires at least 60% for gasification |
| Sec 411 Coal Technology Loans | Earmarks $125M loan to specific project in the act |
| Sec 412 Coal Gasification | Provides loan guarantees for a project of at least 400 MW |
| Sec 413 IGCC Technology | Provides loan guarantees for a project located in a U.S. taconite-producing region |
| Sec 441 Clean Air Coal Program | Authorizes $2 billion for FY2005 to FY2012 for generation and pollution control project |
| Sec 1310 Adv. Nuclear Power | 1.8 cents/kWhr tax credit for an 8-year period after start of operation. Limited to 6,000 MW |
| Sec 1351 Clean Coal Technology | An ITC of 15% for basic clean coal technology units or 17.5% for advanced clean coal technology |
| Sec 1353 IGCC 5-Year Recovery | Provides for Section 1245 property that is part of an IGCC facility to be eligible for a 5-year recovery period |

Table 5-2: Policy Incentives for Electricity Generation Under Consideration in 2003–2004

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# Chapter Six: Quantitative Analysis Results

The quantitative analysis provided a manner for identifying the nature and size of IGCC's market penetration potential under four possible scenarios – environmental constraints, technology progression, natural gas prices, and policy incentives. Each scenario was simulated while the others were held constant so that the impacts of each scenario could be studied in isolation. The quantitative approach examined IGCC's market penetration potential versus its competition during the 2004–2025 timeframe. The capacity growth of other generation technologies also was analyzed to understand the role of competition in IGCC market penetration.

Several different measures of IGCC market penetration were examined:

- Cumulative IGCC capacity additions during the period 2004–2025. Note that cumulative additions appear at the date of initial operation;
- Market share of IGCC additions over the same period; and
- Date by which a given market share, or a number of additions, is achieved.

To analyze the model results, the study examined the model's forecasts of generation capacity additions (total and by technology), fuel and electricity prices, fuel and electricity consumption, pollutant emissions, and allowance values (wherever relevant) as a function of time. The principal standard for assessing market penetration is IGCC cumulative capacity additions from 2004 to 2025. However, two other variables can assist in fully interpreting capacity additions. Because IGCC is an emerging technology, it is critical that early penetration be attained to assure that the technology develops and matures. Therefore, the initial date of IGCC market penetration is significant. Second, IGCC is one of a number of candidates in a complex, inter-related market place and hence, market share can also provide an indicator of the relative competitiveness of IGCC and the volatility of the cumulative capacity additions figure. IGCC additions were compared with those of other technologies to determine market-share trends under each scenario.

Two market impact areas for IGCC were examined:

- Trigger points – the capital cost, efficiency, and the price spreads between natural gas and coal point at which time IGCC initially penetrates the market. Trigger points provide insight into the investment decision dynamics between IGCC and its competitors.
- General trends – trends in both the aggregate power industry and key competitors' market penetration relative to IGCC. Changes in trends from one scenario to another indicate signposts or signals that dictate further examination. For example, high non-fossil market penetration in an environmentally constrained scenario would indicate that pollutant constrains are favorable as non-fossil technologies do not require costly pollution-controls. Comparisons were made across scenarios to determine the sensitivity of IGCC market penetration to different assumptions. Levels and trends for capacity additions, prices, demand, emissions, and allowance values were compared to characterize the full impact of the scenario assumptions across the energy economy, and to determine the chain of influences by which each assumption affected IGCC market penetration.

In total, the quantitative results do not provide the absolute answer to an IGCC investment decision. Quantitative simulations of future market conditions assume rational markets and investment decisions in order to reach a logical answer; however, investment decisions are rarely made on just numerical results. Interested parties generally supplement the quantitative answers with qualitative investment factors to reach an investment conclusion. For IGCC, these factors include, but are not limited to, the availability of performance wraps and governmental loan guarantees, perception of the technology's commercialization readiness, and NIMBY attitudes toward coal-powered generation. Qualitative factors such as these can completely alter a quantitative-based investment decision. Chapter 7 discusses the impacts of these and other IGCC-related qualitative factors in more detail and how they might be mitigated to achieve successful IGCC market penetration.

## 6.1. IGCC can capture market share under a variety of regulatory and environmental scenarios

The environmental benefits of IGCC allow the technology to compete in a variety of regulatory and environmental scenarios. For example, in a Multi-Pollutant scenario, IGCC offers a low-cost mercury removal method that PC currently cannot meet, giving IGCC an advantage in the coal market. In addition, IGCC provides the lowest carbon removal capital costs of any fossil energy generation technology if technologies were to elect carbon capture and disposal over paying carbon allowances. These environmental advantages along with moderate technology advances place IGCC in a much more comfortable market position by 2025.

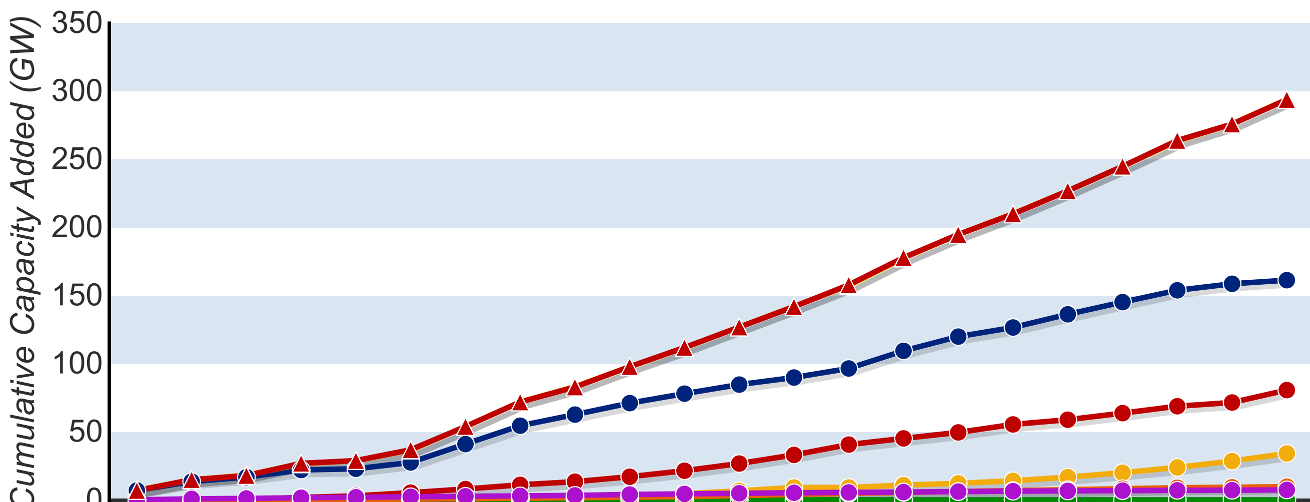
### 6.1.1. Continuing Current Regulatory Framework would be somewhat favorable for IGCC

IGCC is projected to perform well if the current regulatory framework remained unchanged into the future (Figure 6-1). In total, the analysis results in an IGCC addition of 34 gigawatts (GW) of capacity by 2025. This would represent a 12 percent share of the total capacity additions. Under the current regulatory framework, IGCC would begin to enter the market in 2010 without any intervention, such as government subsidies.[19] This indicates that IGCC construction would begin in 2006 since the assumed construction period is four years.

Current Regulatory Framework Trigger Points

| | |
|---|---|
| Penetration Date | 2010 |
| Capital Costs | $1304/kW |
| Heat Rate | 8100 Btu/kWhr |
| Natural Gas Prices | $4.32 - $4.69/MMBtu |
| Natural Gas to Coal Operating Spread | 23–26 mills/kWhr |

In this scenario, PC has a significant starting capital cost advantage of $200/kW that narrows as IGCC technology improves. IGCC, compared to PC, has a small operating cost advantage with respect to




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 5 |
| Coal Combustion | 0 | 0 | 0 | 2 | 3 | 5 | 8 | 11 | 14 | 17 | 22 |
| Natural Gas | 7 | 14 | 17 | 22 | 23 | 28 | 41 | 55 | 63 | 71 | 78 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| Total Capacity Additions | 7 | 15 | 18 | 27 | 29 | 37 | 54 | 72 | 83 | 98 | 112 |

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 7 | 9 | 9 | 11 | 12 | 14 | 17 | 20 | 24 | 29 | 34 |
| Coal Combustion | 27 | 33 | 41 | 45 | 50 | 56 | 59 | 64 | 69 | 72 | 81 |
| Natural Gas | 85 | 90 | 97 | 110 | 120 | 127 | 136 | 145 | 154 | 159 | 161 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 |
| Non-Fossil | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 8 |
| Total Capacity Additions | 127 | 142 | 158 | 178 | 195 | 210 | 227 | 245 | 264 | 276 | 294 |

Figure 6-1: Cumulative Additions of Electricity Generation Capacity, 2004–2025 Under Current Regulatory Framework

[19] How to read this text box: the "Penetration Date" shows when the first 500 MW to 1,000 MW of IGCC begin operation. The overnight capital cost and heat rate figures are representative of the penetration date. Note that capital costs do not include the cost of financing. Because capital costs and heat rates are assumed to improve over time with technology progression, the values at the date of penetration are lower than the 2003 values shown in Section 4: Technology Assumptions. Within NEMS, projects are evaluated for economic viability over a three-year period prior to being placed in service. Therefore, natural gas costs to electricity generators and the natural gas to coal operating cost spreads are given in constant 2003 dollars for the period during this "evaluation range." The natural gas to coal operating spread includes operating costs, fuel costs, and allowance costs.

$SO_2$ and $NO_x$ that becomes important as standards become somewhat more restrictive in later years.[20] Under the moderate technology progression scenario, the cost differential between PC and IGCC also diminishes, making IGCC more competitive with PC. IGCC attains 30 percent of the coal market share of new generation capacity in this scenario.

Beyond the coal market, there are significant signposts and general trends in this scenario. As in the Multi-Pollutant scenario, natural gas technologies lead the market share in capacity additions, gaining 161 GW or 55 percent of the 294 GW in total additions. Natural gas technologies include combined cycle and simple technologies as described in Chapter 4. In all the scenarios, combined cycle represents the majority of natural gas technology additions.

Natural gas technologies do well in the Current Regulatory Framework because of their low capital costs. Further, the current regulatory system plays to natural gas technologies strengths because it emits no $SO_2$ and is the best-performing fossil technology for controlling $NO_x$.

The study found several "trigger points" (reported in constant 2003 dollars) that indicate favorable conditions for IGCC. One trigger point is the capital cost differential of natural gas and coal technologies versus their respective operating costs. The second trigger point is the capital cost differential between PC and IGCC. These triggers are summarized below:

- Coal Trigger: The first "trigger" under this scenario is the spread between the costs of operating NGCC facilities and coal plants. In 2004, there is approximately a $650 to $850/kW capital cost differential between NGCC and available coal technologies. In order to bridge this vast gap, the operating cost differential between the two technologies must be fairly large, on the order of 25 mills/kWhr. In the analysis, the major difference in operating cost comes from fuel costs. In 2004 the fuel cost for using gas is about 40 mills/kWhr and that for coal at about 13 mills/kWhr or a gas-coal spread of about 27 mills/kWhr. Allowing for a 3-year lag, this spread triggers the addition of 2 GW of coal capacity in 2007. Cyclical trends in gas prices result in a lowering of gas price in 2008 and reduction of the operating cost spread to 24 mills/kWhr in 2005, with a corresponding drop in coal capacity additions in 2008. Coal additions follow a cyclical pattern, lagging the operating cost trigger of about 25 mills/kWhr by two years, and are limited to 1-2 GW. In 2015, the gas-coal cost spread begins to increase monotonically and coal additions rise to levels of 6 to 8 GW/yr.
- IGCC Trigger: The second "trigger" is the capital cost spread between IGCC and PC plants. In the "first wave" of coal market penetration from 2007 to 2015, PC gains 79 percent of coal capacity additions because it is cheaper than IGCC by a margin that ranges from $100/kW to $200/kW. IGCC picks up 33 percent of this market during this period because it is able to use lower-cost, high sulfur fuel and pays slightly less in $SO_2$ and $NO_x$ allowance costs. However, in the "second wave," from 2016 to 2025, IGCC capital costs are much closer to PC[21] and IGCC gains 50 percent of coal additions.

A major signpost under this scenario is the trend in natural gas prices. The two "waves" of coal development are responses to two types of gas price increases. The first represents the cyclical interaction of supply and demand, whereas the second represents long-term depletion of the gas resource. Developers of IGCC should carefully monitor the details of the gas market and use the most accurate forecasting tools available to analyze the future costs of gas. With no change in regulation or technology progression, NGCC would be the benchmark for competition and it is only vulnerable if gas costs increase substantially relative to coal.

The Current Regulatory Framework encourages existing generation capacity to install pollution controls through a program of allowance trading. This has a primary effect on older plants that would be retired if economics did not support retrofits or allowance purchase. In this scenario, the analysis suggests that 82 GW of capacity will be retired by 2025, opening the door for more efficient technology. As a result, coal power generation capacity factors rise from 73 percent in 2004 to 84 percent in 2025 capacity and natural gas capacity factors rise from 28 percent in 2004 to 32 percent in 2025. Because NGCC is the dominant technology, increased use of capacity will drive up the price of natural gas and

[20] Under the terms of the Clean Air Act of 1990 as amended.

[21] The difference in capital cost is $73/kWhr in 2017 and $0 in 2025.

accelerate the attractiveness of coal technologies in the second wave. Appendix D has more on capacity factors.

### 6.1.2. IGCC benefits from Multi-Pollutant Regulation

IGCC performs the best in a Multi-Pollutant Regulation scenario. In total, IGCC is projected to add 74 GW of cumulative capacity by 2025. This represents a share of 25 percent of the total capacity additions. Under Multi-Pollutant Regulation, the results suggest IGCC would enter the market in 2010. It also becomes the principal coal technology of a Multi-Pollutant scenario that attains 96 percent of the coal market share of new generation capacity by 2025.

Multi-Pollutant Regulation Trigger Points

| | |
|---|---|
| Penetration Date | 2010 |
| Capital Costs | $1363/kW |
| Heat Rate | 8129 Btu/kWhr |
| Natural Gas Prices | $4.35 - $4.74/MMBtu |
| Natural Gas to Coal Operating Spread | 23–26 mills/kWhr |

Under this regulatory framework, IGCC has a significant capital cost advantage within the coal sector as PC must add $120/kW for activated carbon injection to meet the 70 percent MACT for mercury. IGCC, on the other hand, is capable of achieving 95 percent or better mercury control using sulfur-impregnated activated carbon beds at a cost of less than 1 percent of baseline overnight capital costs.[22] IGCC also performs well in a world of stricter $SO_2$ emissions as it can readily handle high-sulfur coal. Tighter $SO_2$ requirements will shift more PC facilities toward low-sulfur coals, which in turn will drive down the cost of high-sulfur coals. IGCC therefore would benefit from the cost differential between low and high sulfur coals in a further constrained $SO_2$ emissions scenario.

Eastman Chemical has demonstrated the capability of IGCC mercury removal since its gasifiers started in 1983. The activated carbon beds operate at approximately 30°C (86°F) and 900 psi and last 12 to 18 months based on a buildup in pressure, a buildup in water in the bed, or a buildup of other contaminants. Eastman operates its activated-carbon beds upstream of the acid gas removal (AGR) process. The capital costs of IGCC mercury control is minimal when translated to cost of electricity – $0.254/MWhr based on a 15% capital recovery factor – and was assumed in the overnight capital costs.

Source: *Major Environment Aspects of Gasification-Based Power Generation Technologies, December 2002.*

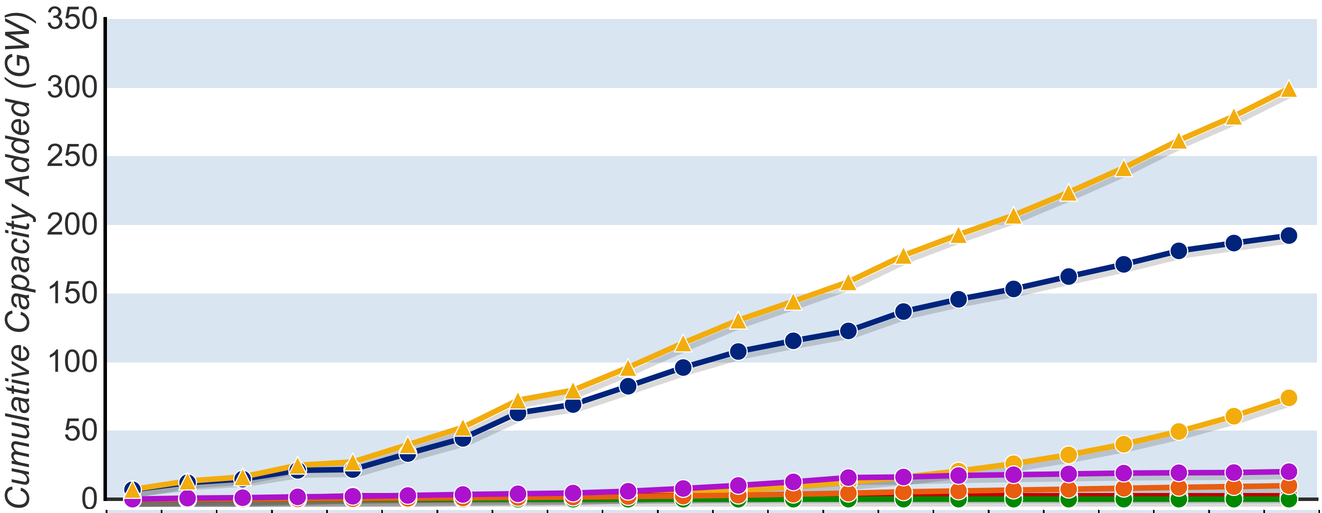
Beyond the coal market, there are significant signposts and general trends in the Multi-Pollutant Regulation scenario. Continuing a trend common throughout most of the scenarios, natural gas technologies are projected as the predominant technology, attaining 192 GW, or 64 percent of the 299 GW in total additions. Natural gas technologies' dominance in this and other scenarios result from its low capital costs and its low emissions; no additional emission control technology is required unless carbon constraints are implemented. IGCC, on the other hand, would have to install SCR for $NO_x$ control and PC would have to install an SCR for $NO_x$ control and carbon injection for mercury control to meet the emission control levels of a Multi-Pollutant world. (The amount of emissions emitted by each pollutant in each scenario can be found in Appendix D.)

Figure 6-2 shows that Multi-Pollutant Regulation is most favorable to IGCC penetration.

A signpost is the emerging possibility of market penetration of non-fossil technology. Because non-fossil plants emit no regulated substances, they have an advantage in the Multi-Pollutant scenario because they are not burdened by capital costs for $NO_x$ and mercury pollution controls.

Retirements in the Multi-Pollutant scenario allow more efficient technologies, such as IGCC, to enter the market. The Multi-Pollutant Regulation scenario projects greatly increased retirements of existing capacity because old coal-fired plants must conform to the $NO_x$ and mercury requirements. Retirements are projected to increase by 7 GW over the Current Regulatory Framework scenario. As inefficient coal capacity is retired, the remaining generating equipment is used at a higher capacity. The capacity utilization for gas-fired plants is projected to reach a level of 37 percent in the Current Regulatory Framework scenario to 39 percent in the Multi-Pollutant Regulation scenario. In turn, increased usage drives up the price of natural gas creating a spread between gas and coal operating costs that acts as a brake on natural gas technologies additions and permits non-gas technology to penetrate the market. Appendix D contains additional retirement information.

[22] IGCC's baseline overnight capital costs of $1400/kW include mercury controls where PC's baseline overnight capital costs do not.




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 12 | 16 | 21 | 26 | 32 | 40 | 50 | 61 | 74 |
| Coal Combustion | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Natural Gas | 7 | 12 | 15 | 21 | 22 | 33 | 45 | 63 | 69 | 82 | 96 | 108 | 116 | 123 | 137 | 146 | 153 | 162 | 171 | 181 | 187 | 192 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 7 | 8 | 9 | 9 | 10 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 8 | 10 | 13 | 16 | 16 | 17 | 18 | 19 | 19 | 19 | 20 | 20 |
| Total Capacity Additions | 7 | 13 | 16 | 25 | 27 | 40 | 53 | 72 | 80 | 96 | 114 | 131 | 144 | 159 | 178 | 193 | 207 | 224 | 242 | 262 | 279 | 299 |

Figure 6-2: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Regulation

Sensitivity analyses were also conducted to examine the impacts of several potential mercury restrictions in the Multi-Pollutant Regulation environment. The issues assessed in these sensitivity analyses include mercury trading, removing the mercury safety valve, and higher mercury restrictions.

Figure 6-3 shows the impact of these sensitivities on IGCC market penetration. IGCC capacity additions essentially are immune to varying mercury sensitivities. This is due to PC being the only competitor technology that emits mercury and being almost completely displaced in the base Multi-Pollutant scenario at reduction levels above 70 percent.

Sensitivity Analyses Around Critical Mercury Control Elements

- Emission Levels: In the Multi-Pollutant scenario, mercury emission levels were based on applying maximum achievable control technology (MACT) to achieve a 70% reduction; some have argued for higher levels. The study team performed a sensitivity analysis for a 90% MACT which showed very little effect on IGCC market penetration since the 70% level greatly reduced additions of new PC capacity.

- Trading: Attainment of mercury emission reductions through allowance trading (as is now done for $SO_x$ and $NO_x$) has been widely debated. Since the multi-pollutant scenario imposed a 70% MACT directly; a sensitivity analysis allowing mercury trading was run. It demonstrated that allowing the 70% reduction to be achieved by trading would delay the onset of IGCC penetration by four years but could increase total IGCC capacity additions by about 3%.

- Safety Valve: As with other environmental controls, several legislative proposals would cap mercury emission allowance costs, providing a "safety valve" to smooth the transition in the short run. The most frequently mentioned safety valve is $35,000/lb. of mercury. The study simulated a scenario a 70% MACT with no safety valve. The result was that a safety valve would have little effect on IGCC market penetration.

### 6.1.3. IGCC represents the coal technology of the future under a Multi-Pollutant Plus Carbon scenario

Adding carbon restrictions results in 41 GW of IGCC added by 2025. This represents a 14 percent share of the total capacity additions. Under Multi-Pollutant Regulation Plus Carbon, IGCC would enter the market in 2010.[23] Of the 41 GW added, IGCC with carbon sequestration represents 5 GW of capacity additions while the remaining 36 GW elects to pay carbon allowances. The initial phase carbon restriction in 2010 stimulates approximately half of the IGCC with carbon sequestration to enter the market. The other half enters the market between 2022 and 2025.

[23] In a multi-pollutant world, the cost of coal operations rises because of environmental compliance cost; the spread between the costs of gas and coal remains below the margin necessary to displace gas until 2010; this critical spread occurs one to two years earlier, when environmental regulations are less strict.

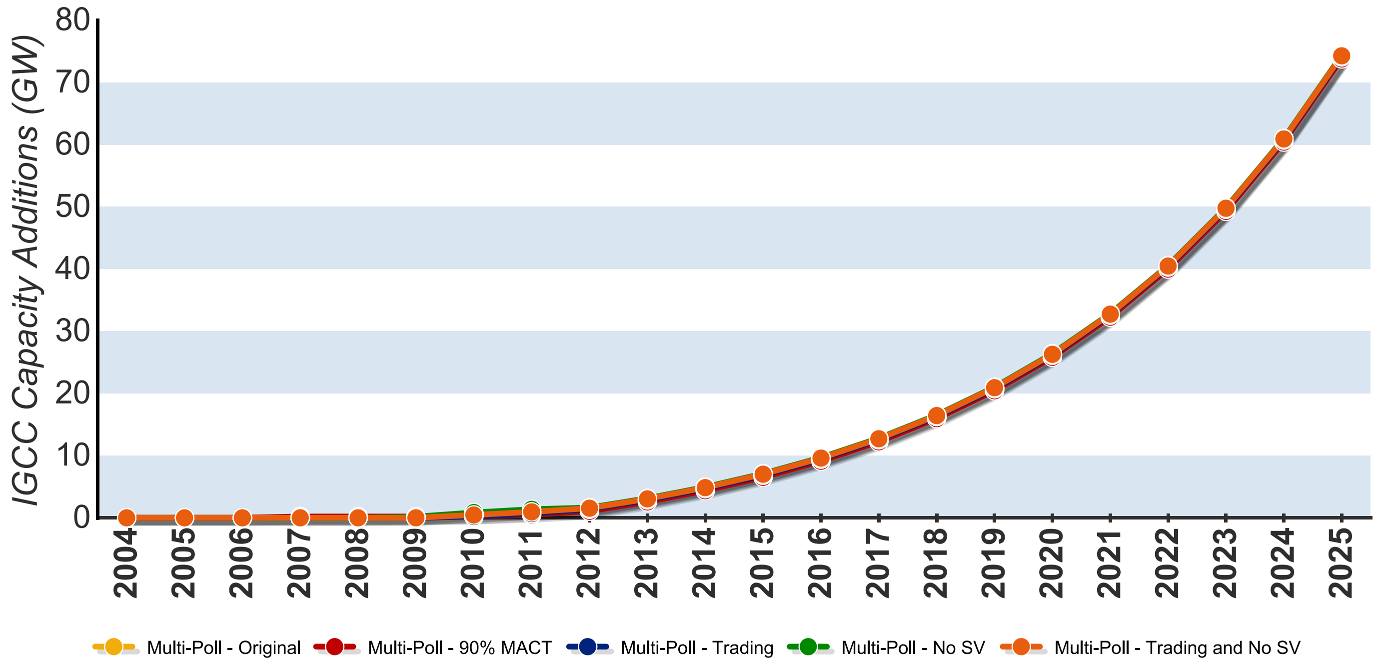



Figure 6-3: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Regulation: Mercury Sensitivity Analyses

A closer look at the modeling results (in Figure 6-4) suggests that the timing and level of restrictions are critical determinants of IGCC market penetration. The carbon constraints were applied in two stages and only to the electricity generation sector. In 2010 emissions were capped at 621 million metric tons of carbon-equivalent (MMTCE), approximately the amount of carbon generated by the electricity sector in 2005. The first constraint allows IGCC with carbon sequestration to penetrate the market in 2010 with 1 GW, representing all of the IGCC additions. IGCC with carbon sequestration then grows to 2 GW under the first phase of carbon constraints. Meanwhile, IGCC without carbon sequestration enters the market in 2014 with 2 GW and adds a total of 4 GW by the end of the first phase carbon constraint. IGCC without carbon sequestration overtakes the carbon sequestration option because technology improvements allow IGCC to produce power more economically and efficiently thus reducing carbon emissions. As a result, paying carbon allowances becomes a more attractive option at the end of the first phase carbon constraint than sequestering carbon.

In 2016 emissions were capped at 492 MMTCE, approximately the levels in 1990. During the second phase of carbon constraints, IGCC without sequestration continues to dominate the IGCC market, adding approximately 4 GW per year from 2016 to 2025. IGCC with sequestration, however, begins to reenter the market in 2022 as technology costs and performance improve. By 2025, IGCC with sequestration adds 5 GW of capacity.

Regional cost factors also play a role in choosing between sequestration and paying allowances. For IGCC, the regional cost factors vary more than PC cost factors due to inherent cost uncertainties of an emerging technology. As a result, regional cost factors can economically outweigh the cost of nationally traded carbon allowances. This provides IGCC with opportunities to penetrate the market.

In a Multi-Pollutant Plus Carbon regulation scenario, natural gas technologies continue to be the predominant technology, attaining 186 GW, or 65 percent of the 287 GW in total additions. Natural gas technologies' dominance results from its low capital costs and its low emission of regulated pollutants. Of the natural gas technologies, NGCC is the favored natural gas technology and is preferred over all coal technologies for several reasons. First, when carbon restrictions are combined with the Multi-Pollutant Regulation scenario, the operating cost between gas and coal technologies increase in the beginning. NGCC emits 725 lbs. of $CO_2$ per MWhr, whereas IGCC emits 1,690 and PC emits 1,700. Thus, the allowance cost per kWhr for gas technology is half that of coal technology.

**Multi-Pollutant Plus Carbon Regulation Trigger Points**

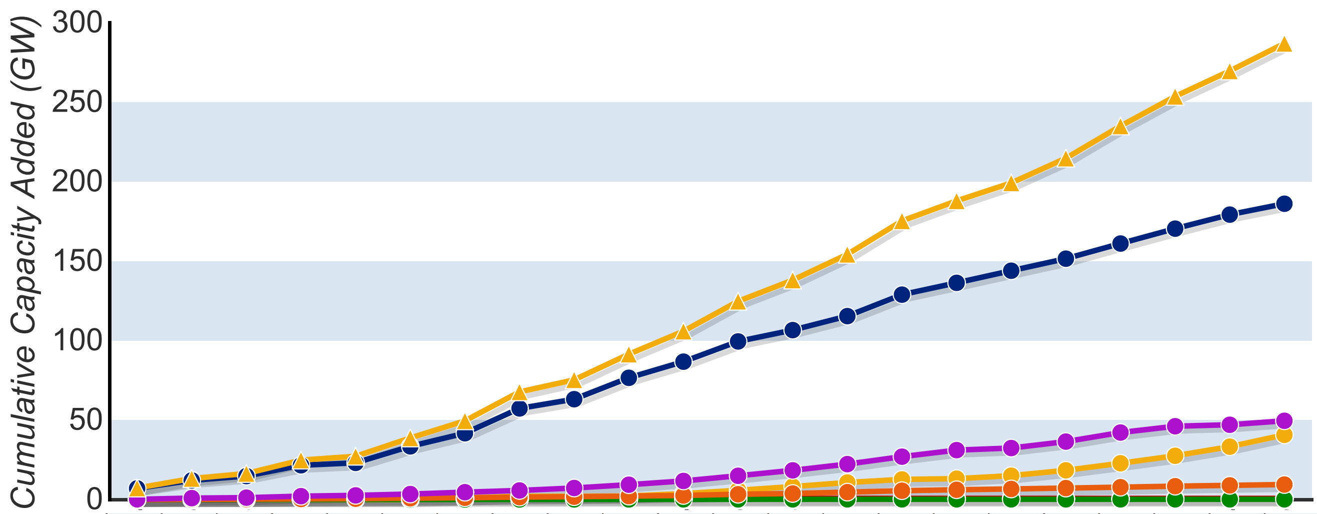
| | IGCC | |
|---|---|---|
| | Sequestration | Non-Sequestration |
| Penetration Date | 2010 | 2014 |
| Capital Costs | $1763/kW | $1294/kW |
| Heat Rate | 9607 Btu/kWhr | 7934 Btu/kWhr |
| Natural Gas Prices | $4.36 - $4.75/ MMBtu | $5.00 - $5.07/ MMBtu |
| Natural Gas to Coal Operating Spread | 23-25 mills/ kWhr | 23–25 mills/ kWhr |

In a carbon-constrained scenario, a spread of about 24–26 mills/kWhr between the fully loaded operating cost of gas and coal is required to sustain IGCC development. This relationship holds from 2009 to 2015. However, the second phase carbon constraint is activated in 2016 and the operating cost spread drops below 20 mills/kWhr for several years. As a result, non-fossil technologies are able to move ahead of IGCC because they pay no carbon allowance costs. IGCC picks up some capacity as gas costs increase and raise the operating cost differential but continues to be at a slight disadvantage relative to NGCC and non-fossil technologies.

A second reason for NGCC dominance in a carbon-constrained scenario is that the capital cost of coal technologies would increase due to non-carbon emission controls. IGCC would have to install $NO_x$ controls and PC would have to install both mercury and $NO_x$ controls; whereas NGCC already would meet the requirements of $NO_x$ and mercury emission constraints.

Within the coal market, IGCC with 41 GW would be the predominant coal technology in a carbon-constrained world. IGCC attains 100 percent of coal's market share of new generation capacity after 2010 due to its lower carbon control capital costs ($400/kW vs. $800/kW) and its lower efficiency penalty (6 percentage points vs. 12.5 percentage points).

Beyond the coal market, there are significant signposts and general trends in the Multi-Pollutant Plus Carbon scenario. The cost of carbon regulation drives up electricity costs and reduces the overall demand for electricity and for new capacity. Additions to capacity drop to 287 GW from roughly 299 GW in the Multi-Pollutant Regulation scenario. Although this amount is lower than in the Multi-Pollutant Regulation scenarios, it provides hope that the Nation's secure low-cost coal resource can be used in the future.[24]




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 4 |
| Coal Combustion | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Natural Gas | 7 | 12 | 15 | 22 | 23 | 34 | 42 | 57 | 63 | 77 | 87 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| Non-Fossil | 0 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 12 |
| Total Capacity Additions | 7 | 13 | 16 | 25 | 27 | 39 | 50 | 68 | 75 | 91 | 106 |

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 6 | 8 | 11 | 13 | 13 | 15 | 18 | 23 | 28 | 33 | 41 |
| Coal Combustion | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Natural Gas | 100 | 107 | 115 | 129 | 136 | 144 | 152 | 161 | 171 | 179 | 186 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 3 | 4 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 10 |
| Non-Fossil | 15 | 18 | 22 | 27 | 31 | 32 | 37 | 42 | 46 | 47 | 50 |
| Total Capacity Additions | 125 | 138 | 154 | 175 | 188 | 199 | 215 | 235 | 254 | 270 | 287 |

Figure 6-4: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Plus Carbon Regulation

[24] Imposition of the "multi-pollutant plus carbon" regulations would represent a present-value cost to the public of approximately $272 billion in increased electricity cost based on the difference in total electricity bill to the public between the "multi-pollutant plus carbon" scenario and the Current Regulatory Framework scenario over the period 2003–2025 discounted at 3 percent; of this about $256 billion is the present value cost of environmental compliance over the same period.

Recommendation: Increase R&D to lower costs of fossil fuel carbon controls.

Another trend is that IGCC and NGCC primarily pay the carbon allowance costs instead of adding costly carbon controls. Combined cycle without sequestration represents 237 GW or 97% of the total combined cycle additions. The remaining 7 GW or 3% of the total combined cycle additions uses carbon sequestration, which signals that the costs of paying allowances are lower than the costs of carbon controls on an net present value basis. If carbon control costs were lower, both NGCC and IGCC would take market share away from the non-fossil technologies.

The emerging possibility of non-fossil technology market penetration as a head-to-head competitor with IGCC represents another signpost. In this scenario, non-fossil technologies would move into the second position with 50 GW in 2025. Non-fossil technologies have no carbon emissions and are therefore not burdened by the carbon allowance cost. Thus, in the carbon regulation scenario, non-fossil becomes a competitor to natural gas with IGCC not far behind. Analysts considering IGCC projects in a carbon-restricted environment will have to monitor both trends in natural gas prices and trends in the cost and performance of non-fossil technologies.

A general trend in carbon-constrained scenarios is the increased level of retirements. Because old coal-fired plants must conform to the $SO_2$, $NO_x$, and mercury emission reductions, and pay carbon allowances or sequester the carbon, coal retirements are projected to increase by 8 GW over the Current Regulatory Framework scenario. Therefore, the results suggest that inefficient coal capacity is retired and the remaining generating equipment is used at a higher capacity. Because natural gas technologies win the dominant share of additions in the years prior to the constraint (34 of 39 GW from 2004 to 2008) and during the mild constraint (66 of 86 GW), the Multi-Pollutant Plus Carbon Regulation scenario tends to drive up the price of natural gas setting the stage for increased penetration of IGCC and non-fossil technologies. In the stricter constraint period (2016–2025), natural gas technologies win 86 of 162 GW.

### Carbon Sensitivities

Sensitivity analyses were also conducted to examine the impacts of two key factors in the Multi-Pollutant Plus Carbon Regulation environment - offsets and stricter carbon regulations:

- Offsets: An offset is a counter-balance or compensation for a particular action or result. Carbon offsets are alternative actions that would reduce carbon introduced into the environment at levels equal to emissions.[25] In the base Multi-Pollutant Plus Carbon scenario, the study simulated "high" offsets, which allows power generators easy access to such alternative carbon reduction techniques. Most legislative proposals include this option (as did the study's scenario), although some have argued against this mechanism. Eliminating offsets would move 196 GW from fossil technology to non-fossil technologies.[26] Natural gas would lose 110 GW of capacity and only 27 GW of IGCC capacity would be added.

Figure 6-5 shows the impact of these sensitivities on IGCC market penetration. The results show that offsets benefit IGCC by approximately 14 GW in 2025. The use of offset has a similar impact on other fossil technologies.

## 6.2. Advances in Technology Greatly Enhance IGCC's Market Penetration Potential

Between now and 2025, electricity generation technology will change, as knowledge is gained from experience in the field and from research, development, and demonstration. The study considered two technology scenarios, a moderate progression based on normal evolution of technology and an advanced progression driven by a focused R&D program. As the investigation of environmental constraints has shown, the performance of each generation technology varies with the number and levels of substances being controlled. This section examines how advances in technology can help IGCC overcome barriers posed by environmental restrictions; hence the interaction between technology and regulation is critical to the future of IGCC.

[25] One potential example is the purchase of forestland that offsets an equivalent amount of $CO_2$ emissions.

[26] Renewables are exempt from carbon restrictions.

### 6.2.1. Technology Advances make IGCC the predominant coal technology in a Current Regulatory Framework scenario

If the Current Regulatory Framework were to continue into the future, advances in technology would result in IGCC displacing much of the growth in PC. In total, Advanced Technology IGCC could add 89 GW of cumulative capacity by 2025, some 55 GW over the Moderate Technology scenario. This would represent a 30 percent share of the total capacity additions. Under the Current Regulatory Framework, advanced technology IGCC could enter the market in 2010.

Current Regulatory Framework Trigger Points

| | |
|---|---|
| Penetration Date | 2010 |
| Capital Costs | $1241/kW |
| Heat Rate | 7556 Btu/kWhr |
| Natural Gas Prices | $4.29 - $4.71/MMBtu |
| Natural Gas to Coal Operating Spread | 23–26 mills/kWhr |

In the Current Regulatory Framework scenario, technology advances narrow the capital cost gap between IGCC and PC very early, and by 2025, advanced IGCC are projected to cost $200/kW less than PC in capital costs. Should the advanced technology scenario be attained, IGCC would become the predominant coal technology, attaining 72 percent of the coal market share of new generation capacity, more than reversing the positions of the two technologies under the Moderate Technology Progression. As shown in Figure 6-6, technology advances help IGCC outpace PC if Current Regulatory Framework continues.

Natural gas technologies would continue to lead market share attaining 158 GW of the 300 GW total additions. The Current Regulatory Framework would favor natural gas technologies over coal technologies, but the increased efficiency of advanced coal technologies would make natural gas technologies more vulnerable to increases in natural gas prices, as discussed later in the study's natural gas price sensitivity analysis.

Under the Current Regulatory Framework, the availability of advanced, more efficient technology leads to additional retirement of existing capacity, mostly older petroleum-based steam generation facilities. Retirements increase from 84 GW under moderate technology progression to 87 GW with advanced technology. The introduction of efficient new technology allows generators to supply the same amount of electricity (100 Bil kWhr) without driving up capacity usage and fuel prices. Gas prices in 2025 are lower ($5.68/MMBtu vs. $6.01/MMBtu) than under moderate technology.

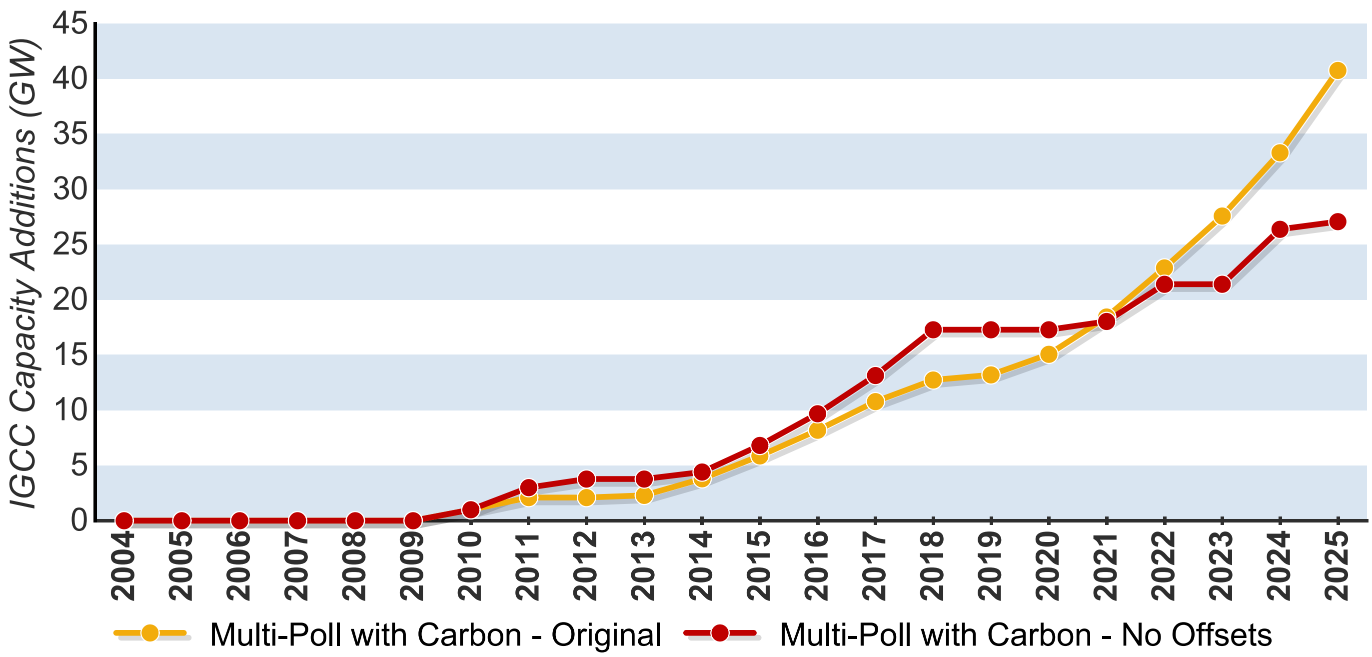



Figure 6-5: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Regulation: Sensitivity to Nuclear Cost and Availability of Offsets

Attainment of the advanced technology would save the general public approximately $10 billion (in 2003 dollars) because of reductions in capital costs and increases in operating efficiencies.[27]

Recommendation: Approach R&D from a short- and long-term perspective to speed market penetration and overall capacity additions.

### 6.2.2. Technology advances helps IGCC achieve maximum penetration under Multi-Pollutant Regulation

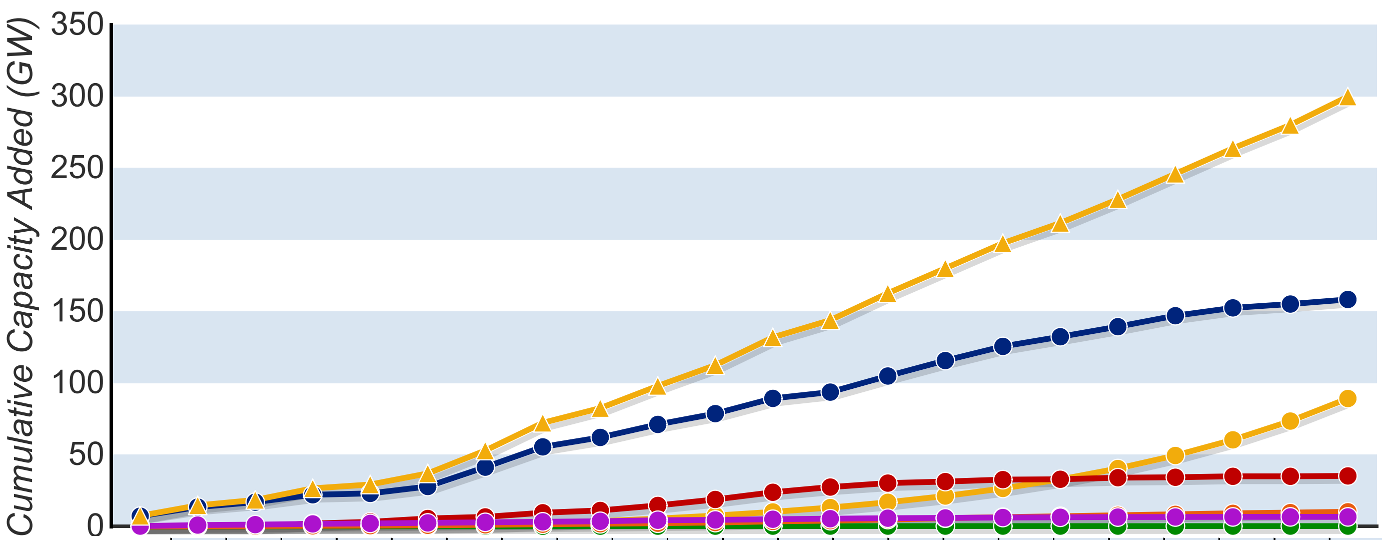
Advanced technology IGCC performs best in a multi-pollutant scenario gaining 98 GW of cumulative capacity by 2025. Improved efficiencies benefit all fossil technologies, and the combination of NGCC and IGCC would dramatically reduce the competitiveness of non-fossil technology. IGCC would capture 32 percent of the total capacity additions. Under Multi-Pollutant Regulation, advanced technology IGCC would enter the market in 2010. Should the advanced technology scenario be reached, IGCC would continue to be the dominant coal technology of a multi-pollutant world attaining 98 percent of the coal market share of new generation capacity. Figure 6-7 shows that technology advances help IGCC achieve maximum penetration under Multi-Pollutant Regulation.

Multi-Pollutant Regulation Trigger Points

| | |
|---|---|
| Penetration Date | 2010 |
| Capital Costs | $1380/kW |
| Heat Rate | 7584 Btu/kWhr |
| Natural Gas Prices | $4.37 - $4.75/MMBtu |
| Natural Gas to Coal Operating Spread | 23–26 mills/kWhr |

With technology advances, natural gas technologies (low in both capital costs and emissions) would maintain the position as the market share leader in capacity additions.

In the Multi-Pollutant Regulation scenario, efficiency improvements result in an increase in the amount of retirements of existing capacity over the Moderate Progression scenario (95 GW vs. 91 GW) and include combustion turbines and petroleum-fired equipment in addition to the coal capacity retired due to stricter emission standards. The increased efficiency of new capacity allows the system to supply slightly more electricity at approximately the same capacity factor. The increased presence of efficient IGCC technology exerts a strong moderating influence on electricity price. Appendix D contains more information on coal and electricity demand.




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 5 | 8 | 10 | 13 | 17 | 21 | 26 | 33 | 40 | 49 | 60 | 74 | 89 |
| Coal Combustion | 0 | 0 | 0 | 2 | 3 | 6 | 7 | 10 | 11 | 15 | 19 | 24 | 27 | 30 | 31 | 33 | 33 | 34 | 34 | 35 | 35 | 35 |
| Natural Gas | 7 | 14 | 17 | 22 | 23 | 28 | 41 | 55 | 62 | 71 | 79 | 89 | 94 | 105 | 116 | 126 | 132 | 139 | 147 | 152 | 155 | 158 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 10 | 10 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 |
| Total Capacity Additions | 7 | 15 | 18 | 27 | 29 | 37 | 53 | 72 | 83 | 98 | 112 | 132 | 144 | 163 | 180 | 198 | 212 | 228 | 246 | 264 | 280 | 300 |

Figure 6-6: Cumulative Additions of Electricity Generation Capacity, 2004–2025 Under Current Regulatory Framework and Advanced Technology

[27] The present value (at 3 percent discount factor) of the nation's total electricity bill under advanced technology, less the same quantity calculated under moderate technology.

### 6.2.3. Advanced Technology allows coal to thrive under Multi-Pollutant Plus Carbon Regulation

Under Multi-Pollutant Regulation Plus Carbon, non-fossil technologies are appealing because they could trade their carbon allowances. However, advances in technology would make IGCC very competitive with non-fossil technologies. IGCC would add a total of 80 GW of capacity by 2025, or 29 percent of the total capacity additions. IGCC with carbon sequestration represents 33 GW of capacity additions while the remaining 47 GW elects to pay carbon allowances. Under Multi-Pollutant Plus Carbon Regulation IGCC would enter the market in 2010.[28]

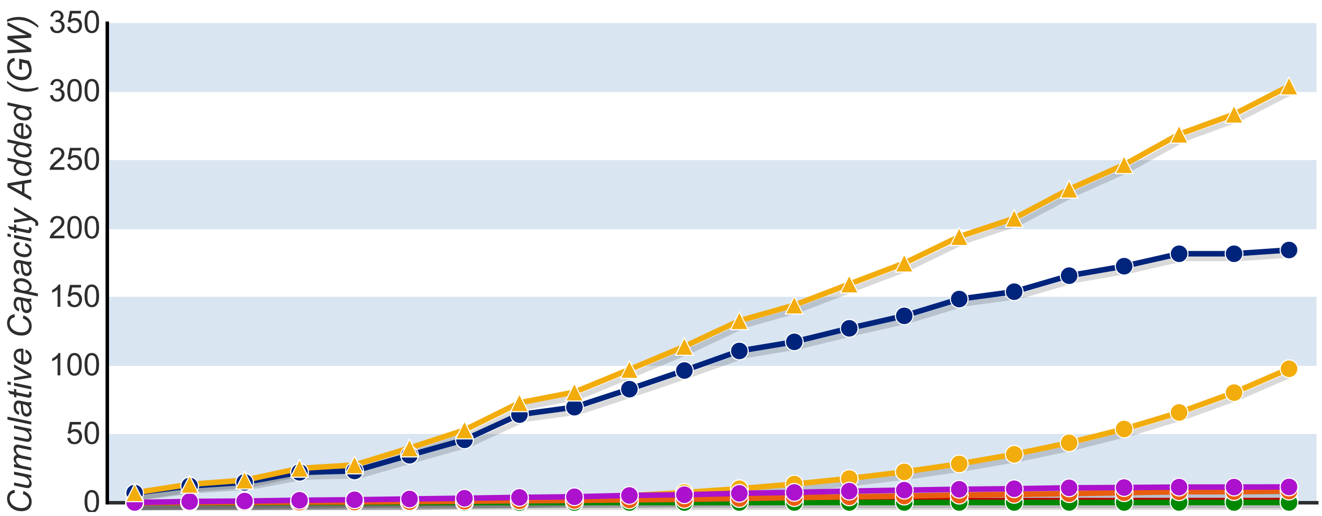
The results suggest that the timing and level of restrictions are critical determinants of the type of IGCC market penetration. The first phase of carbon constraints in 2010 allows IGCC with carbon sequestration to penetrate the market with 2 GW, representing all of the IGCC additions. IGCC with carbon sequestration then grows to a total of 2 GW under the first phase of carbon constraints. Meanwhile, IGCC without carbon sequestration enters the market in 2013 with 2 GW and adds a total of 5 GW by the end of the first phase carbon constraint. IGCC without carbon sequestration eventually dominates the IGCC market as advanced technology improvements allow IGCC to produce power more economically and efficiently. As a result, paying carbon allowances in general becomes a more attractive option as opposed to sequestering carbon.

During the second phase of carbon constraints from 2016 to 2025, IGCC with sequestration represents one-half of all IGCC additions. This sequestration growth is significant compared to the moderate technology progression scenario, indicating that technology advances are important for IGCC market penetration.

As with the moderate technology progression scenario, regional cost factors play a role in choosing between sequestration and paying

Multi-Pollutant Plus Carbon Regulation Trigger Points

| | IGCC | |
|---|---|---|
| | Sequestration | Non-Sequestration |
| Penetration Date | 2010 | 2013 |
| Capital Costs | $1700/kW | $1221/kW |
| Heat Rate | 9062 Btu/kWhr | 7182 Btu/kWhr |
| Natural Gas Prices | $4.36 -$4.79/ MMBtu | $4.85 - $4.96/ MMBtu |
| Natural Gas to Coal Operating Spread | 23-25 mills/ kWhr | 24-25 mills/ kWhr |




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 5 | 7 | 10 | 14 | 18 | 23 | 28 | 35 | 44 | 54 | 66 | 80 | 98 |
| Coal Combustion | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Natural Gas | 7 | 12 | 15 | 22 | 23 | 35 | 46 | 64 | 70 | 83 | 97 | 111 | 117 | 127 | 136 | 149 | 154 | 166 | 173 | 182 | 182 | 184 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 10 | 11 | 11 | 11 | 11 | 12 |
| Total Capacity Additions | 7 | 13 | 16 | 25 | 28 | 40 | 53 | 73 | 81 | 97 | 114 | 133 | 144 | 160 | 175 | 194 | 208 | 229 | 247 | 269 | 284 | 304 |

Figure 6-7: Cumulative Additions of Electricity Generation Capacity 2004–2025 Under Multi-Pollutant Regulation and Advanced Technology

[28] The study methodology gave IGCC and NGCC developers the choice of installing plants with carbon control technology (at a higher front-end cost) or relying on purchasing allowances or offsets. Under this particular carbon constraint, with widely available offsets, developers would not elect to install carbon controls.

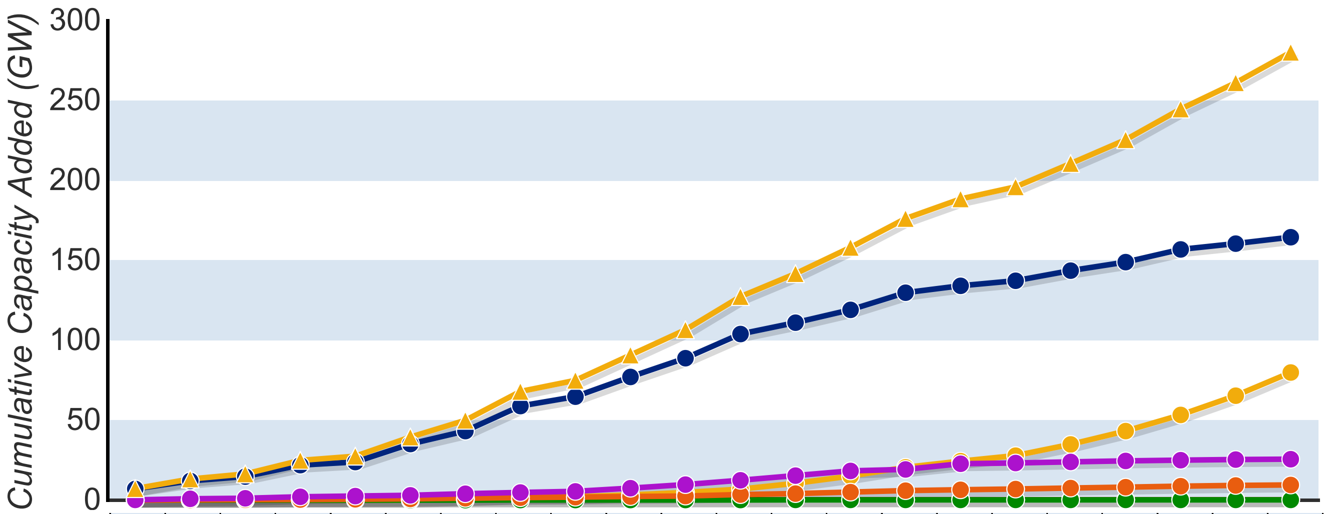
allowances. For IGCC, the regional cost factors vary more than PC cost factors due to inherent cost uncertainties of an emerging technology. As a result, regions with low cost factors can economically outweigh the cost of paying carbon allowances. This provides IGCC with sequestration opportunities to penetrate the market.

Under Multi-Pollutant Plus Carbon regulation, advanced technology IGCC would remain the dominant coal technology gaining 100 percent of the coal market share of new generation capacity. Advanced technology allows coal to thrive under Multi-Pollutant Plus Carbon Regulation. The cost of carbon regulation drives up electricity costs and reduces overall demand for electricity and for new capacity. (Appendix D presents the costs and demand for electricity.) Figure 6-8 represents this scenario.

Because of low capital costs and emissions, natural gas technologies would lead market share in capacity additions, attaining 165 GW of the 280 GW in total additions. However, the lower costs and greatly improved efficiency of advanced technology allows IGCC to compete with NGCC. In this scenario, IGCC captures 19 GW of market share away from NGCC. Similarly, cost reductions in IGCC result in capturing 24 GW from non-fossil technologies as compared to the Moderate Technology scenario and add 7 GW.

In the Multi-Pollutant Plus Carbon Regulation scenario, efficiency improvements from technology advances result in a small increase in retirements as compared to the moderate technology progression scenario (98 GW vs. 94 GW). As new capacity enters the market, increased efficiency allows the system to supply slightly more electricity at approximately the same capacity factor.

The other co-benefits of technology advances are lower electricity prices and a greater use of the nation's coal resources. For example, the increased presence of efficient IGCC technology exerts a strong moderating influence on electricity prices (see Appendix D). With the advanced technology, IGCC and the non-fossil technologies can displace natural gas technologies. As a result, less gas is used and the cost of electricity (COE) drops from 8.6 cents/kWhr under moderate technology to 8.4 cents/kWhr under advanced technology. In both technology scenarios, demand is 98 B kWhr, but deployment of the advanced technology would deliver this amount of electricity at considerable savings. Attainment of the advanced technology would save the general public approximately $35 billion in electricity costs (in 2003 dollars) because of reductions in capital cost and increases in operating efficiencies.[29]




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 5 | 7 | 11 | 15 | 21 | 24 | 28 | 35 | 43 | 53 | 65 | 80 |
| Coal Combustion | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural Gas | 7 | 12 | 15 | 22 | 24 | 35 | 43 | 59 | 65 | 77 | 89 | 104 | 111 | 119 | 130 | 134 | 137 | 144 | 149 | 157 | 161 | 165 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10 |
| Other Non-Fossil | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 8 | 10 | 13 | 15 | 18 | 19 | 23 | 23 | 24 | 25 | 25 | 25 | 26 |
| Total Capacity Additions | 7 | 13 | 16 | 25 | 28 | 40 | 50 | 68 | 75 | 91 | 107 | 127 | 142 | 158 | 176 | 188 | 196 | 211 | 225 | 245 | 261 | 280 |

Figure 6-8: Cumulative Additions of Electricity Generation Capacity, 2004–2025 Under Multi-Pollutant Plus Carbon Regulation and Advanced Technology

[29] The present value (at 3 percent discount factor) of the nation's total electricity bill under advanced technology, less the same quantity calculated under moderate technology.

## 6.3. Advanced Technology Analysis

One of the biggest challenges facing IGCC is getting earlier penetration and more market growth than demonstrated by the model. In the NEMS modeling, technology improvements over time were straight-lined from the starting points to 2025 estimated endpoints. This approach was chosen because it removed the subjectivity surrounding improvement timings. To refine and assess technology progression's individual impacts, the study team developed the power-pricing model. The purpose of the power-pricing model is to help determine which R&D technologies are best suited for maximizing overall market penetration

The Power Pricing Model examines a particular technology's effect on improving IGCC's Return on Investment (ROI). The ideas for the technology improvements came from literature reviews, study participants' input, and in particular from the U.S. DOE's Report DOE/FE-0447, "Technologies—Present and Future: An Industry Perspective."

### 6.3.1. Power Pricing Model and the ROI Tornado Diagram

The Power Pricing Model is a simple discounted cash flow model that examines how technology improvements affect IGCC's ROI. ROI is the ultimate metric for valuing an investment. Technology improvements were simulated in this model by changing the investment input factors impacted. These input factors and their base inputs are listed in Table 6-1.

| Investment Input Variable | Units | Base Value |
|---|---|---|
| Capital Cost | $/kW | 1400 |
| Availability | % | 93 |
| Efficiency (HHV) | % | 40.5 |
| Fixed Operating Costs | $/kWyr | 33.8 |
| Variable Operating Costs | $/MWhr | 4.0 |

Table 6-1: Investment Input Factors

Other assumptions affecting the investment decision, but not varied, are included in Table 6-2.

| Assumption | Units | Base Value |
|---|---|---|
| Construction Period | Years | 4 |
| Debt Percentage | % | 55 |
| Equity Percentage | % | 45 |
| Cost of Debt | % | 6.5 |
| Cost of Equity (after tax) | % | 13.75 |
| Tax Rate | % | 40 |
| Coal Cost | $/MMBtu | 1.25 |
| Whole Sales Price of Electricity | $/MWhr | 44.36 |
| Annual Inflation | % | 2.5 |

Table 6-2: Assumptions Affecting Investment Decision

The sensitivities of input variables were analyzed by varying each by 5 percent at a time. The purpose of this sensitivity analysis was to examine which variables had the greatest impact on ROI. For example, a 5 percent increase in wholesale electricity prices would raise ROI to 11.0 percent from 10.0 percent, while a 5 percent decrease in wholesale electricity prices would lower ROI to 9.2 percent from 10.0 percent. The results were placed in an ROI Tornado diagram, shown in Figure 6-9, to visually demonstrate the variables' impacts.[30]

As the ROI Tornado Diagram demonstrates, availability and capital costs have the largest influence on the IGCC investment decision, whereas efficiency and operation and maintenance costs have the smallest impact. Therefore, technology advancements affecting mainly availability and capital costs will have the greatest impact on IGCC's market penetration.

### 6.3.2. Individual Technology Analysis

The Power Pricing Model was then used to analyze individual technology advancements. This allowed a ranking, and appropriate recommendations, of technology advancements focus areas based on ROI impact. The technology advancements analyzed are the following:

- No Spare Gasifier: This scenario assumes that a spare gasifier is no longer needed results from improvements in solids handling, feed injectors, refractory, flux for reducing ash fusion temperatures, and instrumentation and control.

[30] The Tornado Diagram concept was taken from Eastman Chemical's NPV Tornado Diagram and reapplied in an ROI format.

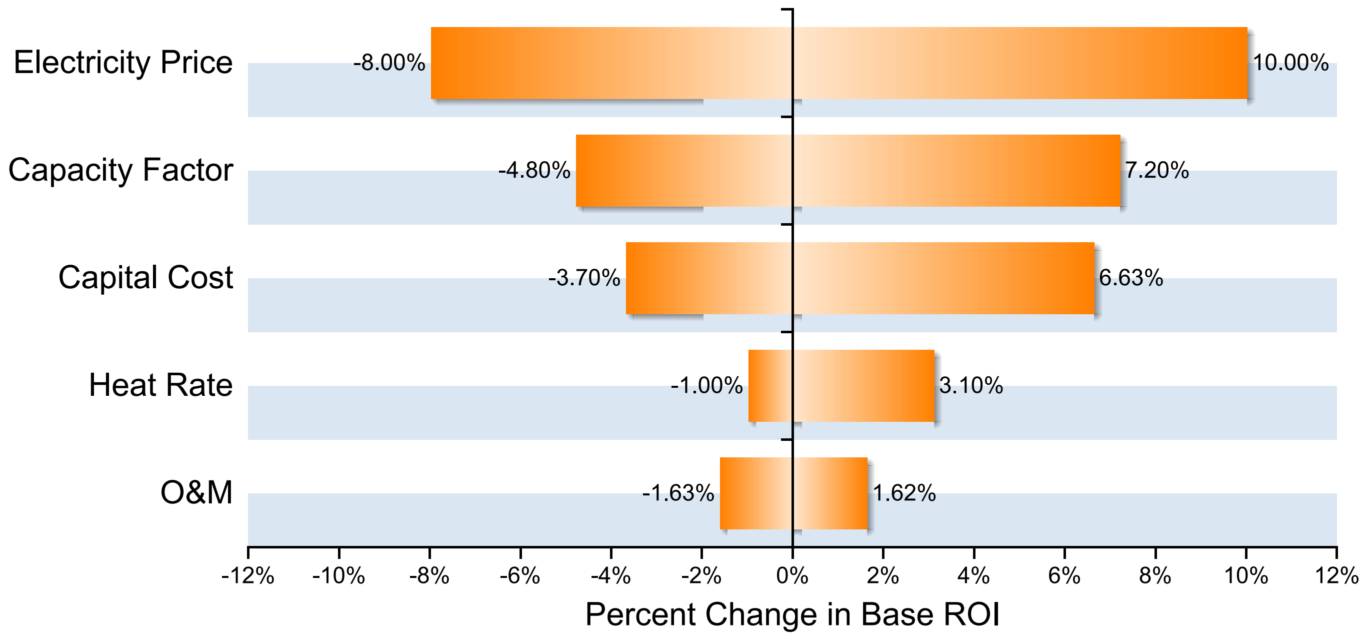



Figure 6-9: ROI Tornado Diagram

The two-train IGCC plant will maintain the same availability as the two-train IGCC plant with a spare gasifier.

- Increased Carbon Utilization: Current gasifier technologies average 95 percent carbon utilization, whereas others can obtain 98 percent. This scenario assumes that all gasifier technologies are capable of achieving 98 percent carbon utilization.
- Integration with FB Turbines: Considerable effort is being devoted to integrating and optimizing FB turbines with syngas.
- Warm-gas cleanup: Moving to a warm-gas cleanup system from a cold-gas cleanup system could reduce capital needed, lower O&M costs, and improves efficiencies for IGCC.
- Membrane Separation: ITMs and OTMs would replace cryogenic ASUs.
- Integration with G and H Turbines: Integrating and optimizing G and H turbines on syngas would lower capital costs and dramatically improve efficiencies.
- Fuel Cells: Fuel cell integration presents the benefit of significantly increasing efficiencies and lowering emissions.
- Standard Plant Design: There are no standard IGCC plant designs at this time because there are only four operating coal-based IGCC units worldwide. Standardizing plant design would lower capital costs through replication.

Table 6-3 lists the impact of each of these technologies on ROI, from highest to lowest.[31]

| Technology Advancement Focus Area | % ROI Increase |
|---|---|
| No Spare Gasifier | 14.8 |
| Integration with G and H Turbines | 8.0 |
| Standard Plant Design | 7.8 |
| Warm-gas cleanup | 7.7 |
| Membrane Separation | 6.5 |
| Fuel Cells | 6.2 |
| Integration with FB Turbines | 5.2 |
| Increased Carbon Utilization | 2.8 |

Table 6-3: Impacts of Technologies on ROI

The ROI ranking provides an objective look at which technology focus areas should receive the most attention for R&D purposes. The ranking also allowed the study team to rate the highest priority improvements within short- and long-term contexts. In the short term, the study team examined those high-ranking ROI improvements that were most feasible for moving forward IGCC penetration dates.

[31] The input data for the technology advancements was taken from Gray, D., Salerno, S., & Tomlinson, G.

The long-term ranking focused on increasing IGCC's overall market penetration. The end result of the analysis was to recommend the most probable and influential R&D investments that will maximize overall market penetration, considering the constraints of R&D spending.

From the perspective of short-term, early market penetration, the following R&D focus areas would most benefit IGCC, ranked from highest to lowest:

- Eliminating the spare gasifier;
- Standardizing plant design; and
- Increasing carbon utilization.

The recommended long-term R&D focus areas, ranked from highest to lowest on an ROI basis, are as follows:

Recommendation: Approach R&D from both a short and long-term perspective to help earlier IGCC penetration.

- Integrating and optimizing G, FB, and H frame turbines on syngas;
- Achieving warm-gas cleanup; replacing cryogenic ASUs with membrane separation technologies; and
- Developing low-cost, highly efficient, and scalable fuel cell technologies.

### 6.3.3. The Influence of Successful R&D on ROI

The ROI ranking provides an objective perspective on which R&D advancements will most impact IGCC market penetration. The results of this analysis depend on successes in Federal R&D. For example, eliminating the spare gasifier will rely on improvements in coal handling, feed injectors, refractory reliability and durability, and instrumentation and control. It is expected that most of these issues to be resolved within the next five years.

Integrating with G and H frame turbines requires significant effort in optimizing the turbine combustors on syngas. In addition, advances must be made in designing the combustors to meet 2–3 parts per million (ppm) $NO_x$ control. Improvements in $NO_x$ control will eliminate the costly need of adding a SCR. The FB frame turbines face similar issues; however, their projected improvements do not affect ROI as much as the G and H frames.

Warm-gas cleanup ranks high in its ROI impact, but the technology has much development still needed. For one, the technology modeled in the Power Pricing Model was Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) process. It has yet to be demonstrated on a large scale (membrane separation has similar R&D issues). In addition, the technology's success is tied to the ability to remove mercury at higher temperatures. Current mercury removal technologies operate slightly above ambient temperatures, and no high temperature mercury removal system has been proven.

Successful deployment of fuel cells would have significant impact on ROI. Advancement of fuel cells show the possibility of obtaining even higher efficiencies than modeled in the Power Pricing Model. Furthermore, the fuel cell's potential cross-fertilization R&D impacts of technologies could spur changes in the transportation industry and the hydrogen economy.

## 6.4. The Impact of Higher Natural Gas Prices

In the previous sections, the report has focused on how regulation and technology can affect capital costs, operating costs, and efficiency among competitor technologies. That is, under various regulatory systems, electricity generation technologies would be required to incur different cost and efficiency penalties for adding pollution control equipment. Similarly, the report assessed the impact of technology advances in reducing the capital costs, operating costs, and heat rates of technology that stem from R&D. In each scenario, situations have been found in which the balance was tipped in favor of non-gas technology and (often) in favor of IGCC. This section, however, investigates the impact of changes in fuel cost holding regulation and technology constant.

Even though NGCC has a fairly large advantage in capital cost and is the dominant technology in most scenarios, non-gas technologies may penetrate the market place when natural gas fuel costs are high relative to its competitors. Fuel costs factored with the plant efficiency, variable-operating costs, fixed operating costs, and allowance costs represent the total plant operating costs. Unit fuel cost, efficiency, regulation, and technology are the major drivers of operating cost:

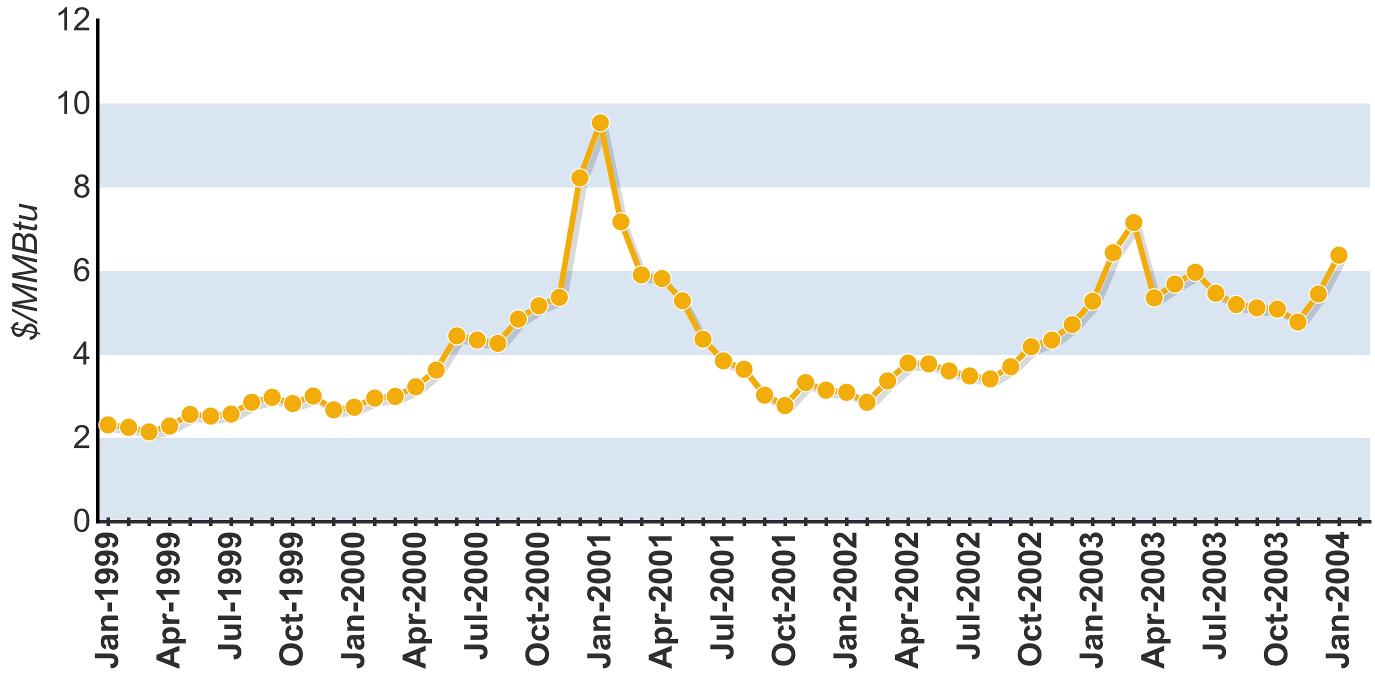



Figure 6-10: Natural Gas Prices to Electric Utilities, Monthly 1999-2003
EIA's "Average Price of NG Sold to Electric Utility Consumers"

- The unit cost of fuel, particularly natural gas, is the largest single component of operating cost.
- Efficiency determines the amount of fuel, which must be consumed to generate each kWhr of electricity.
- Regulation affects operating costs through the allowances and penalties, which must be paid on the basis of substances emitted by each generation technology.
- Technology affects operating cost through improved efficiency, requiring less fuel to generate the same amount of electricity, or through reducing the cost of removing pollutants.

Natural gas prices, however, are the principal component of operating cost and, hence, a major determinant in IGCC market penetration. Unlike coal, natural gas prices have been extremely volatile in recent years and have been projected with much uncertainty as well. As a result, the uncertain future of natural gas prices has made potential IGCC investors hesitate. Historical natural gas prices to electric utilities are shown in Figure 6-10.

Current Regulatory Framework Trigger Points

| | |
|---|---|
| Penetration Date | 2010 |
| Capital Costs | $1304/kW |
| Heat Rate | 8100 Btu/kWhr |
| Natural Gas Prices | $4.77 - $4.12MMBtu |
| Natural Gas to Coal Operating Spread | 27-30 mills/kWhr |

The study investigated two gas price scenarios to evaluate the differences in IGCC's market penetration potential from natural gas. These two scenarios are briefly described below and are discussed in greater detail in Chapter 5:

- Base Gas Price Scenario: Natural gas prices closely resemble EIA's most recent estimates in the "AEO 2004," with significant increases over previous EIA forecasts.
- Higher Gas Price Scenario: Natural gas prices closely resemble the "Reactive" (or High) price scenario in the September 2003 appraisal of the NPC. In representing this price curve, the actual mid-December gas price futures' curve was used to 2009 and then a linear trend to the NPC Reactive Scenario price estimate for 2025 was taken.[32]

In Figure 6-11, the "High" scenario mirrors the NPC Reactive scenario and the "Base" scenario mirrors AEO 2004.

[32] This was done by empirically adjusting parameters within NEMS to produce this result for the Current Regulatory Framework, moderate technology case that closely approximates the regulatory and technological assumptions of the NPC. NEMS was not constrained to use particular prices; different regulatory and technological assumptions produce gas price trends that may differ from this. Gas prices are reported in constant 2003 dollars throughout this report.

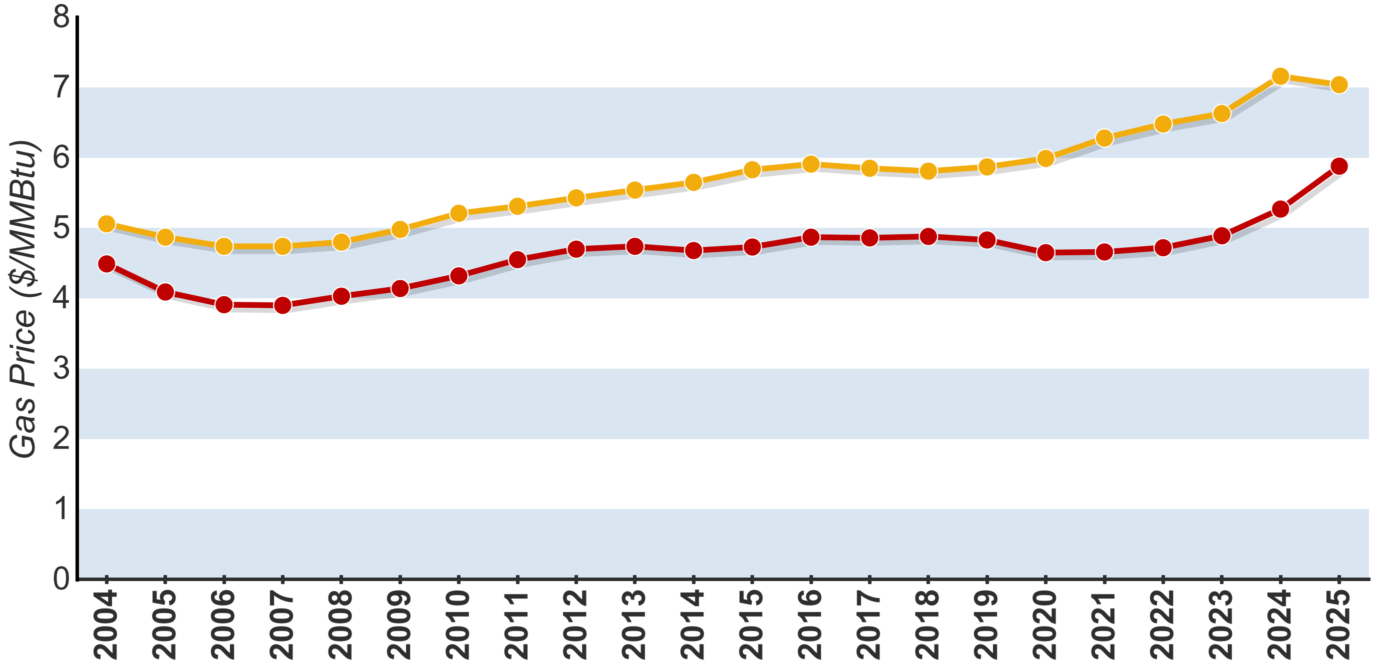



Figure 6-11: Gas Price Trends, 2004–2025
Natural Gas Price Sensitivity Scenarios

Natural gas prices in the "High Scenario" are approximately $0.50/MMBtu higher than in the "Base Scenario" on a real cost basis, and this results in a more even mix of new capacity across technologies. The earlier discussions of the IGCC market potential under various environmental constraints and alternative pace of technology advancement were based on the Base Gas Price Scenario. This section discusses changes to those assessments based on the Higher Gas Price Scenario.

### 6.4.1. High Gas Prices would result in Coal dominance if Current Regulatory Framework continues

Under the current regulatory framework and high natural gas prices, coal technologies overtake natural gas as the principal fuel choice, with PC the dominant technology. IGCC would add 67 GW of cumulative capacity by 2025 as compared to 34 GW in the base natural gas price scenario. This represents a 22 percent share of the total capacity additions. Under Current Regulatory Framework IGCC would enter the market in 2010.

In this scenario, high gas prices encourage investments in all simulated coal technologies. Because PC has the lowest capital, it captures 109 GW of capacity, or 62 percent of the coal share. Should the future look like the high gas price scenario then IGCC would attain 38 percent of the coal market share of new generation capacity.

With advances in technology, the coal market would grow to 124 GW. With high gas prices and cost reductions through R&D, IGCC could attain 131 GW, or 71 percent of the coal market (and 41 percent of the total additions).

High gas prices would result in coal dominance if Current Regulatory Framework continues as seen in the graph (Figure 6-12).

Under the high gas price scenario, natural gas technologies would no longer represent the predominant technology group, attaining only 115 GW of the 308 GW total additions and is second to coal technologies with 176 GW. Natural gas technologies lose its previously dominant position because high natural gas prices economically outweigh its low capital costs.

High gas prices under the Current Regulation scenario result in slightly increased overall retirements as compared to the base gas price scenario. However, this masks two opposing trends: existing coal and non-fossil retirements are lower and combustion turbine and petroleum steam retirements are higher. Because of high gas prices, existing coal capacity would be used at about 82 percent capacity, whereas gas-fired generation would be reduced to 23 percent, down from the 33 percent capacity in the base gas price curve scenario.

### 6.4.2. High Gas Prices would intensify competition between IGCC and Natural Gas Technologies under Multi-Pollutant Regulation

IGCC continues to be the dominant coal technology in a multi-pollutant regime; this scenario is also the earliest the study shows IGCC penetration without incentives. Added costs of emission controls for IGCC allow non-fossil technologies to gain market share. In total, IGCC adds 109 GW of cumulative capacity by 2025 as compared to 74 GW in the base natural gas price. This represents a 35 percent share of the total capacity additions. Under Multi-Pollutant Regulation and high gas prices, IGCC would enter the market in 2009.

Multi-Pollutant Regulation Trigger Points

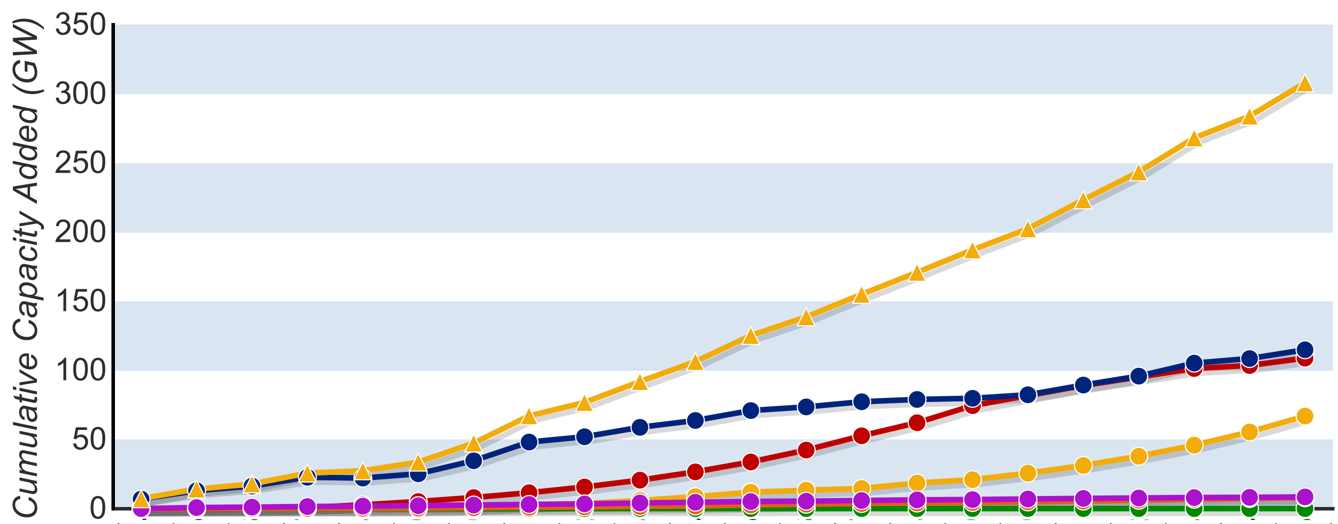
| | |
|---|---|
| Penetration Date | 2009 |
| Capital Costs | $1381/kW |
| Heat Rate | 8177 Btu/kWhr |
| Natural Gas Prices | $4.82-$5.12 MMBtu |
| Natural Gas to Coal Operating Spread | 27-29 mills/kWhr |

Under Multi-Pollutant Regulation, high gas prices encourage both IGCC and non-fossil technologies, but PC technology is greatly limited by stricter controls on mercury. Should the future look like the high gas price scenario then IGCC would attain 97 percent of the 112 GW in coal market share of new generation capacity. Non-fossil generation would add 36 GW. If the advanced technology were achieved, IGCC would achieve 164 GW of capacity largely at the expense of the non-fossils.

Figure 6-13 illustrates how high gas prices would intensify competition between IGCC and natural gas technologies, with IGCC capturing the majority of capacity after 2011.

Natural gas technologies lead market share in capacity additions from 2004 to the end of 2011, attaining 54 GW of total additions. After 2011, natural gas technologies gain 102 GW of new capacity while IGCC adds 107 GW. IGCC becomes the dominant fossil-fuel technology after 2011 due to its cost-effective mercury control and low fuel costs.

The Multi-Pollutant Regulation scenario combined with high gas prices has significant impact on the total the amount of retirements; 101 GW would be retired as compared with 91 GW under base gas prices. Because of high gas prices, slightly fewer existing coal-fired plants (which must conform to the $NO_x$ and the mercury requirements) would be retired (14 GW vs. 15 GW under base gas prices) as compared to the base natural gas price scenario. Instead, natural gas combustion turbines and petroleum steam plant retirments would increase. Coal capacity would continue to be used at about 82 percent capacity, whereas gas-fired capacity would drop from 34 percent to 20 percent as a result




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 6 | 9 | 12 | 13 | 15 | 19 | 21 | 26 | 31 | 38 | 46 | 56 | 67 |
| Coal Combustion | 0 | 0 | 0 | 1 | 3 | 5 | 8 | 12 | 16 | 21 | 27 | 34 | 43 | 53 | 62 | 75 | 82 | 89 | 95 | 102 | 104 | 109 |
| Natural Gas | 7 | 13 | 16 | 23 | 22 | 25 | 35 | 48 | 52 | 59 | 64 | 71 | 74 | 77 | 79 | 80 | 83 | 90 | 96 | 105 | 109 | 115 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 8 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 8 | 8 | 8 | 8 | 9 |
| Total Capacity Additions | 7 | 14 | 18 | 26 | 28 | 34 | 48 | 67 | 77 | 92 | 106 | 125 | 139 | 155 | 171 | 187 | 203 | 223 | 244 | 268 | 284 | 308 |

Figure 6-12: Cumulative Additions of Electricity Generation Capacity, 2004–2025 Under Current Regulatory Framework and High Gas Prices

of high gas prices. Even with drop in gas capacity utilization, the modeling suggest that gas prices could reach levels of $7.67 in 2025.

### 6.4.3. Under High Gas Prices IGCC could dominate a future with Multi-Pollutant Plus Carbon Regulation

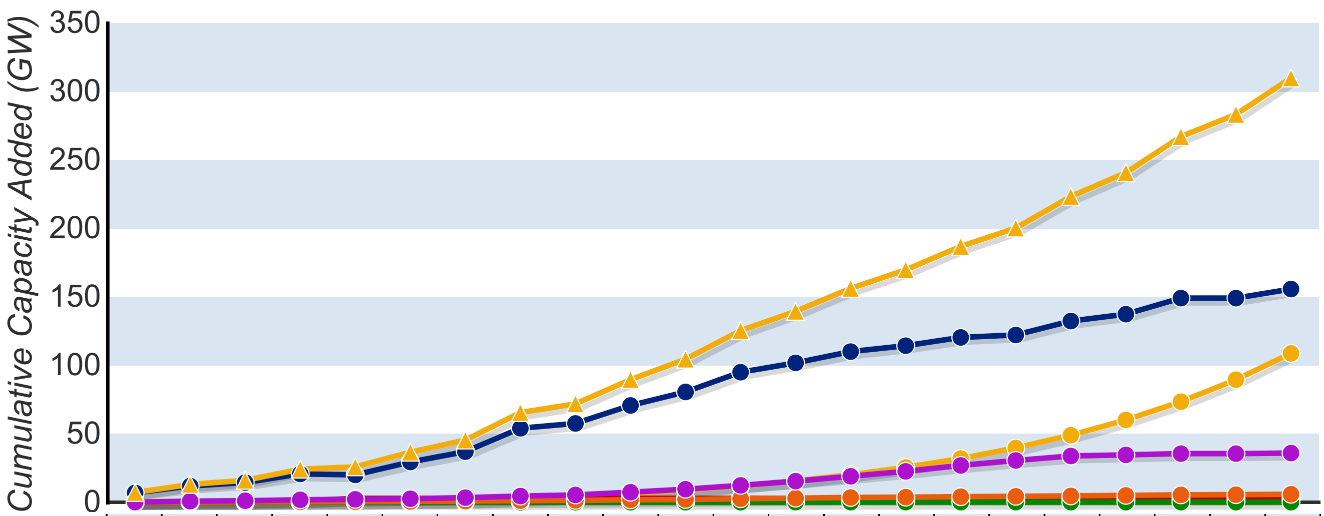
Under Multi-Pollutant Plus Carbon Regulation, high gas prices are advantageous for both IGCC and non-fossil technologies. IGCC's first point of entry is in 2010. During the first phase of carbon reduction (2010–2016) moderate technology IGCC adds 14 GW to non-fossil technologies' 29 GW. In the second, stricter phase, IGCC adds 72 GW of capacity to non-fossils 39 GW, making IGCC the leader in market share. If the future were to become the high gas price scenario, then IGCC would attain 98 percent of an 88 GW coal market share in new generation capacity.

In a world of high natural gas prices and carbon constraints, IGCC approximately matches natural gas technologies in fossil energy market share from 2010 to 2025. IGCC and natural gas technologies add 86 GW and 87 GW of capacity, respectively. IGCC with carbon sequestration represents 6 GW of capacity additions while the remaining 80 GW elects to pay carbon allowances. IGCC with carbon sequestration additions enter the market in 2011 at 2 GW and end at 6 GW in total additions by 2025. The IGCC with carbon sequestration additions again are due to regions that have lower capital costs for IGCC. Non-fossil technologies add 68 GW or 24 percent of the total cumulative capacity (285 GW) by 2025. See Figure 6-14.

In the Multi-Pollutant Plus Carbon Regulation scenario, under high gas prices, 100 GW of capacity is retired, an increase from the 94 GW of capacity retired under base gas prices. Coal retirements are down and gas and petroleum retirements are accelerated because of high gas prices. Coal capacity usage falls from 84 percent to 82 percent levels because of carbon regulations. Similarly, gas capacity usage falls due to carbon regulations. However, increased natural gas prices have the most dramatic effect, dropping gas capacity utilizations from 36 percent to 19 percent. Even with this dramatic drop in gas capacity utilization, the model projects gas prices to reach levels of $8.51 in 2025.

Multi-Pollutant Plus Carbon Regulation Trigger Points

| | IGCC | |
|---|---|---|
| | Sequestration | Non-Sequestration |
| Penetration Date | 2010 | 2011 |
| Capital Costs | $1763/kW | $1347/kW |
| Heat Rate | 9607 Btu/kWhr | 8080 Btu/kWhr |
| Natural Gas Prices | $4.92 - $5.21 MMBtu | $5.13 - $5.29 MMBtu |
| Natural Gas to Coal Operating Spread | 28-29 mills/ kWhr | 29mills/kWhr |




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 4 | 6 | 9 |
| Coal Combustion | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Natural Gas | 7 | 12 | 15 | 21 | 20 | 30 | 37 | 54 | 58 | 71 | 81 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 7 | 10 |
| Total Capacity Additions | 7 | 13 | 16 | 24 | 26 | 37 | 46 | 66 | 72 | 90 | 105 |

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 12 | 16 | 20 | 26 | 32 | 40 | 49 | 60 | 74 | 90 | 109 |
| Coal Combustion | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Natural Gas | 95 | 102 | 110 | 114 | 121 | 122 | 132 | 137 | 149 | 149 | 156 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 6 |
| Non-Fossil | 12 | 16 | 19 | 23 | 27 | 31 | 34 | 35 | 36 | 36 | 36 |
| Total Capacity Additions | 125 | 140 | 156 | 170 | 187 | 200 | 223 | 241 | 267 | 283 | 310 |

Figure 6-13: Cumulative Additions of Electricity Generation Capacity 2004–2025 Under Multi-Pollutant Regulation and High Gas Prices

## 6.5. Policy Incentives

Over and above the direct workings of technology, emission regulation and fuel prices, it is also possible to use various governmental mechanisms to selectively encourage early emergence of new technologies. Examples of such methods include direct subsidy, financial guarantees, and tax changes that affect either the front-end and/or annual operating costs. This study examined the effects of some of these selective encouragement techniques. To simulate these incentives, scenarios were developed using electricity generation incentives closely resembling those in the 2004 Conference Report of the Energy Bill. The provisions included in the modeling are detailed in Table 5-2 in Chapter 5.

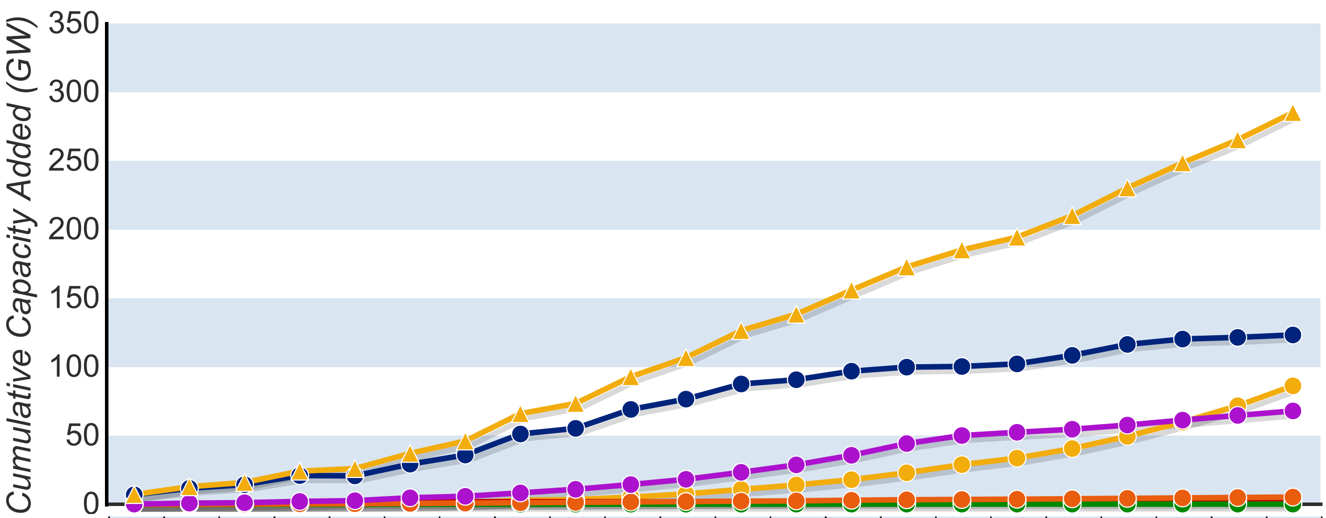
Current Regulatory Framework Trigger Points

| | |
|---|---|
| Penetration Date | 2008 |
| Capital Costs | $1215/kW |
| Heat Rate | 8194 Btu/kWhr |
| Natural Gas Prices | $4.17-$4.29 MMBtu |
| Natural Gas to Coal Operating Spread | 22-23 mills/kWhr |

The study simulated the effect of these incentives by the following methods:

- Reducing capital costs for coal technologies (IGCC, PC, as indicated by the proposal);
- Reducing operating costs for coal technology through the tax credit mechanism;
- Approximating the use of advanced coal technology (IGCC, PC) for repowering existing plants;[33] and
- Decreasing O&M for non-fossil technologies.

Because emission regulations could change during the period in which these incentives would be in effect, the study considered two scenarios: the effect of these incentives assuming no change in emissions regulation, and the effect of these incentives should Multi-Pollutant Regulation be imposed in the near term.[34]




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 5 | 8 | 11 | 14 | 18 | 23 | 29 | 34 | 41 | 50 | 60 | 72 | 86 |
| Coal Combustion | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Natural Gas | 7 | 12 | 14 | 21 | 21 | 29 | 36 | 51 | 55 | 69 | 77 | 88 | 91 | 97 | 100 | 100 | 102 | 109 | 116 | 120 | 122 | 123 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| Non-Fossil | 0 | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 11 | 14 | 18 | 23 | 29 | 36 | 44 | 50 | 53 | 55 | 58 | 61 | 65 | 68 |
| Total Capacity Additions | 7 | 13 | 16 | 24 | 26 | 37 | 46 | 66 | 73 | 93 | 107 | 127 | 138 | 156 | 173 | 185 | 195 | 210 | 230 | 249 | 265 | 285 |

Figure 6-14: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Plus Carbon Regulation and High Gas Prices

[33] The NEMS technique for scheduling planned construction and retrofits that effectively forces such plants to be built was used to approximate the use of IGCC or PC to accomplish re-powering as specified in the legislative proposals. Current case-models of NEMS do not provide for re-powering as an "unplanned" event that would be decided by market economics.

[34] Time did not permit a full analysis of these provisions over all six of the base case scenarios. The two selected provide insights into the ability of these incentives to move forward the emergence of significant market penetration.

### 6.5.1. Under Current Regulatory Framework, policy incentives could make IGCC more competitive with PC.

The primary purpose of the policy incentive analysis was to determine whether governmental incentives would move IGCC's market entry date forward. In the Current Regulatory Framework scenario, policy incentives are projected to move IGCC's market penetration date ahead by 2 years, from 2010 in the base case scenario to 2008 in the policy incentive scenario. In addition, IGCC attains 51 GW or 17 percent share of total new capacity additions by 2025, some 17 GW more than would be added without the policy incentives.

The policy incentives modeled impact coal technology in two ways. First, by lowering the risk of investment through loan guarantees, they effectively lower the capital cost. Second, by providing tax incentives, they lower the annual operating cost. This makes coal more competitive by attacking the principal barriers to its market penetration (i.e., high front-end cost) and emphasizing its strength (i.e., low operating cost). The policy incentives also open opportunities for advanced coal technologies (i.e., IGCC and PC) to be used in re-powering existing coal plants.

The net effect of the incentives is to narrow the capital cost gap between IGCC and PC. With the assumptions included in this modeling, IGCC would become very competitive with PC technology, attaining 43 percent of the coal market share of new generation capacity. (Figure 6-15)

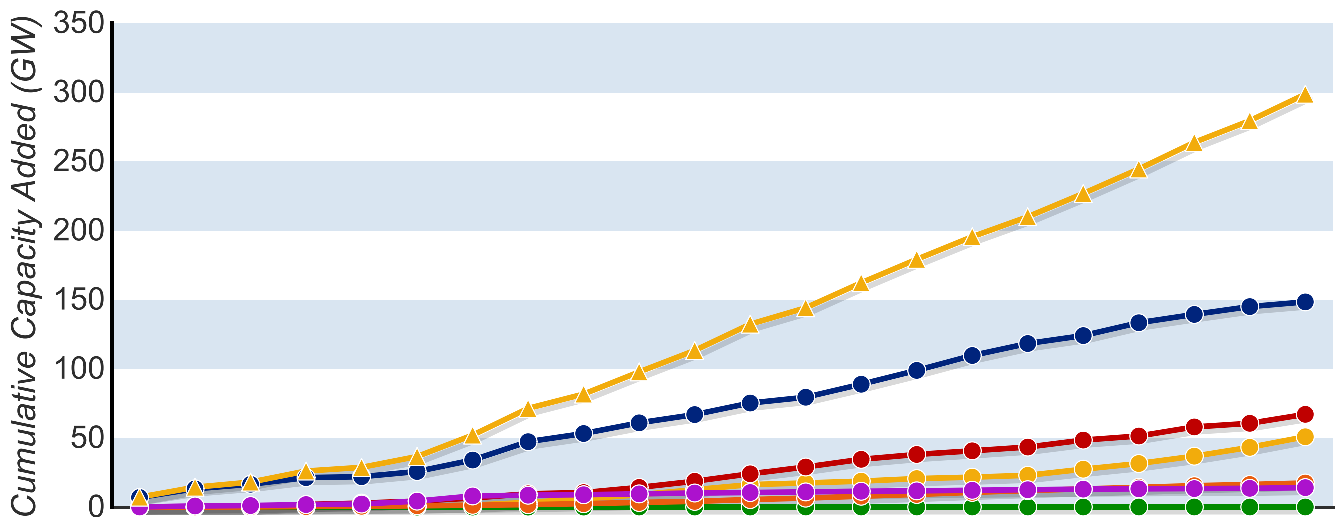
Under Current Regulatory Framework, the re-powering incentives benefit IGCC and PC will lead to a decrease of 3 GW in retirements of existing capacity that would be "reborn" as modern IGCC and PC plants.

### 6.5.2. The policy incentives under Multi-Pollutant Regulation would allow early IGCC market penetration.

Multi-Pollutant Regulation Trigger Points

| | |
|---|---|
| Penetration Date | 2007 |
| Capital Costs | $1265/kW |
| Heat Rate | 8274 Btu/kWhr |
| Natural Gas Prices | $4.15-$4.36 MMBtu |
| Natural Gas to Coal Operating Spread | 22-24 mills/kWhr |

The policy incentives under Multi-Pollutant Regulation would increase IGCC's market penetration date to 2007, which is three years sooner than the base case Multi-Pollutant Regulation scenario with no incentives. This is the earliest IGCC market entry date for all the scenarios.[35] The early market entry date results from the combination of favorable




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 16 | 18 | 19 | 21 | 22 | 23 | 28 | 32 | 37 | 43 | 51 |
| Coal Combustion | 0 | 0 | 0 | 2 | 3 | 4 | 7 | 10 | 11 | 14 | 19 | 24 | 29 | 35 | 38 | 41 | 44 | 49 | 52 | 58 | 61 | 67 |
| Natural Gas | 7 | 13 | 17 | 21 | 22 | 26 | 34 | 47 | 53 | 61 | 67 | 75 | 80 | 89 | 99 | 110 | 118 | 124 | 133 | 139 | 145 | 149 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 4 | 6 | 7 | 8 | 9 | 11 | 12 | 13 | 14 | 16 | 16 | 18 |
| Other Non-Fossil | 0 | 1 | 1 | 2 | 2 | 4 | 8 | 9 | 9 | 10 | 10 | 11 | 11 | 12 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 14 |
| Total Capacity Additions | 7 | 15 | 18 | 26 | 29 | 37 | 52 | 72 | 82 | 98 | 113 | 132 | 144 | 162 | 179 | 196 | 210 | 227 | 245 | 264 | 280 | 299 |

Figure 6-15: Cumulative Additions of Electricity Generation Capacity, 2004–2025 Under Current Regulatory Framework and Federal Policy Initiatives

[35] Because the modeling was performed in 2003, the earliest, reasonable date of IGCC market penetration was 2007 assuming a four-year construction timeline.

advanced coal power generation policy incentives and from changes in emission regulations amenable to IGCC's pollution control characteristics.

In this scenario, IGCC becomes the dominant coal technology, attaining an 85 percent share of the coal market. PC is projected to add 16 GW of cumulative capacity in this scenario, but most of this is earmarked in the incentives package modeled as "repowerings." Total IGCC additions would be 93 GW, 19 GW more than the base scenario with no policy incentives. IGCC represents 31 percent of the total new capacity additions by 2025. Figure ES-4 summarizes the results of the simulated policy incentives for the Current Regulatory Framework and the Multi-Pollutant Regulation scenarios.

The entire suite of policy incentives as modeled would encourage early development of IGCC in a multi-pollutant scenario, with market entry beginning in 2007. IGCC will gain 93 GW of cumulative capacity by 2025. In this scenario, IGCC would capture 31 percent of the total capacity additions.

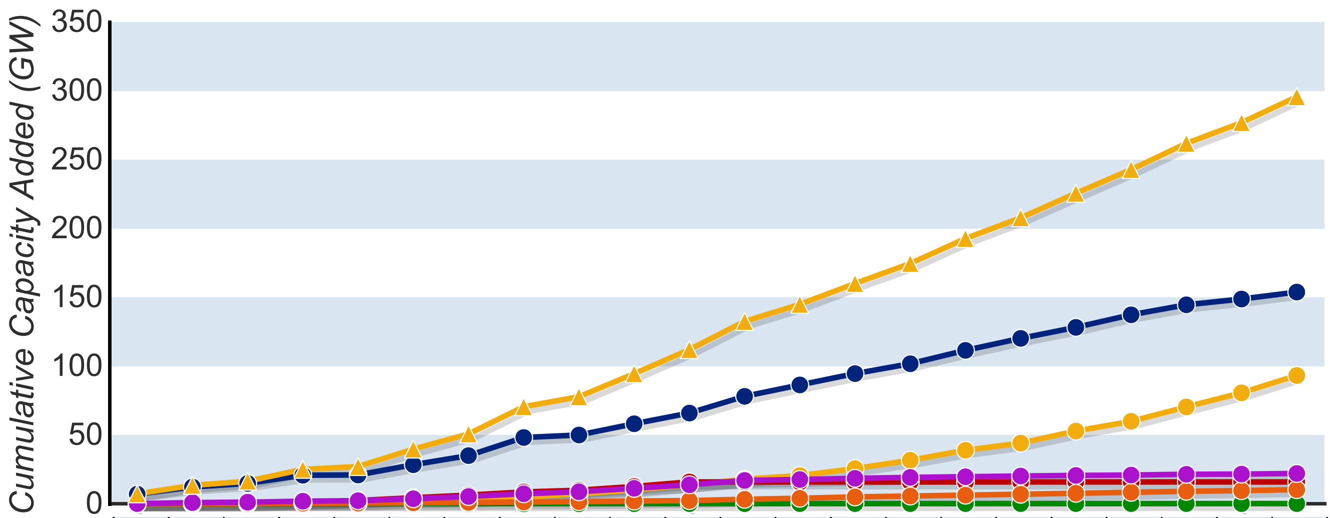
As modeled, IGCC would be the dominant coal technology of a multi-pollutant world attaining an 85 percent share of a coal market. PC would add 16 GW in this scenario, but most of this is earmarked in the incentives package modeled as "repowerings."

Natural gas technologies (low in both capital costs and emissions) would be the predominant electricity generation technology. Natural gas technologies would lose about 38 GW under the incentives to 154 GW of the 296 GW in total additions. Figure 6-16 illustrates the indivudual technology capacity additions.

## 6.6. Conclusions

The market penetration of IGCC reflects a complex tradeoff of capital cost and operating cost. In general, NGCC is the predominant generation technology for the period 2004 to 2025 because of its very low capital cost. However, the increasing scarcity of natural gas and consequent rise in gas prices makes NGCC vulnerable on the fuel component of operating cost, which allow the penetration of non-gas technologies including non-fossil technologies, PC, and IGCC. Changes in environmental regulation also affect the capital and operating costs. Some of these changes, particularly mercury regulation tip the balance in favor of IGCC while other regulations such as carbon constraints favor non-fossil as long as there are no advancements in technology and natural gas prices remain low to moderate. R&D that yields lower cost, more efficient technology is a major benefit to IGCC. Federal policies including subsidies and tax incentives can accelerate the penetration of IGCC.

As environmental restrictions increase, the use of coal as a fuel stock increasingly becomes dependent on IGCC's successes. IGCC does best under a Multi-Pollutant Regulation that plays to its strong suit in controlling mercury. However, even in




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IGCC | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 10 | 14 | 18 | 21 | 26 | 32 | 39 | 44 | 53 | 60 | 70 | 81 | 93 |
| Coal Combustion | 0 | 0 | 0 | 1 | 2 | 4 | 6 | 9 | 10 | 13 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Natural Gas | 7 | 12 | 15 | 21 | 21 | 28 | 35 | 48 | 50 | 58 | 66 | 78 | 86 | 95 | 102 | 112 | 120 | 128 | 137 | 145 | 149 | 154 |
| Fuel Cells | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Distributed Generation | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 10 | 10 |
| Non-Fossil | 0 | 1 | 1 | 2 | 2 | 4 | 5 | 7 | 9 | 11 | 14 | 17 | 18 | 19 | 19 | 20 | 20 | 21 | 21 | 21 | 22 | 22 |
| Total Capacity Additions | 7 | 13 | 16 | 25 | 27 | 40 | 51 | 71 | 78 | 95 | 112 | 133 | 145 | 160 | 175 | 193 | 208 | 226 | 243 | 262 | 277 | 296 |

Figure 6-16: Cumulative Additions of Electricity Generation Capacity, 2004–2025
Under Multi-Pollutant Regulation and Federal Policy Initiatives

the most favorable regulatory environment, IGCC is vulnerable to potential competition from non-fossil technologies and would require significant advances in technology to attain its full potential.

Technology advance was the most robust strategy for achieving IGCC market penetration. In all scenarios, lowered costs and improved efficiencies through R&D provided the key to maximum penetration into the market.

Under the Current Regulatory Framework scenario, coal technologies would continue to account for about a third of the new additions. However, in the advanced technology scenario, IGCC would displace PC as the dominant coal technology. Under Multi-Pollutant Regulation, coal technologies would have a diminished role, although IGCC would be the survivor. Advances in technology would permit IGCC to increase its share of new capacity from 22 percent to 37 percent. Thus, advanced technology IGCC would be critical if coal is to contribute in a more restricted environment.

In the carbon-constrained scenarios, coal technologies are at a disadvantage, gaining 15 percent of the market. Because non-fossil technologies emits no regulated substances and would receive carbon allowances, it would make significant penetration in the moderate technology scenarios; however, fuel cells could allow both IGCC and NGCC to compete with non-fossil technologies in the advanced technology scenarios.[36] Advanced technology IGCC, the sole surviving coal technology, could capture 37 percent of the market.[37]

IGCC market penetration is not appreciably affected by alternative proposals for Multi-Pollutant Regulation because mercury regulation affects only competition between IGCC and PC in which IGCC has a significant advantage. Note that this study did not model mercury constraints less than the 70 percent reduction level. However, the regulatory system for carbon regulation has broad implications for all fossil energy technology, IGCC included. Without allowances and offsets, fossil technologies are projected to have a reduced role in a carbon-constrained future.

Rising natural gas prices mean that natural gas power plants would reduce their capacity factors, thus promoting retirements at costly facilities.

As natural gas facilities retire, the demand for electricity generation capacity would increase, especially for coal-power generation. In the current environmental regime with high natural gas prices, all coal does well. IGCC doubles in its capacity additions over the projections with a lower gas price curve, whereas conventional coal combustion increases by 35 percent.

With the multi-pollutant scenarios, high gas prices would accelerate trends observed under the base gas price scenario: (a) there will be virtually no new coal combustion projects; and (b) there will be strong growth in IGCC and non-fossil technology at the expense of new natural gas additions.

High gas prices and carbon regulation would work against NGCC to the benefit of IGCC and non-fossil technology. However, much of the non-fossil growth could be vulnerable to IGCC, especially through advanced technology. Policy incentives can accelerate the penetration of IGCC, a necessary condition for attaining the critical mass of successful projects that would be required to demonstrate the market viability of the technology. However, it is unlikely that policies would be specifically tailored to favor IGCC, and the effects of such incentives could be muted, especially if both PC and non-fossil technologies were to be included in the package.

The very best future for IGCC is one that plays to its strengths and minimizes its weaknesses. This would occur if these conditions were met:

1. Successful R&D lowers the capital and operating costs of IGCC.
2. The government elects to require at least a 70 percent reduction in mercury emissions.
3. The spread between gas and IGCC operating cost increases beyond 25 mills/kWhr.
4. Federal tax policy encourages early development of IGCC.

Under these conditions, the country might well expect to see over 130 GW of IGCC capacity added between 2004 and 2025.

[36] The results may change after 2025 if the Generation 4 reactors can come online.

[37] With allowances and offsets, both IGCC and NGCC would elect not to use carbon controls.

Overall, the study uncovers trends for IGCC's market penetration. The primary trends are that technology advances affect the relative positioning of the individual technologies and the environmental constraints set the tone for IGCC penetration relative to its competitors. IGCC is the dominant coal technology in all environmentally constrained regimes and predominate in the more restrictive regimes. Other determinants that impact IGCC's market penetration are higher natural gas prices that would help coal in general, and policy incentives, as such as those contained in the in the Energy Bill that would result in earlier penetration of IGCC.

# Chapter Seven: Qualitative Assessment

The NEMS and Power Pricing models permit analysis of factors that are defined in quantitative terms. However, many arguments for and against IGCC investment depend on factors that are not as easily quantified. These qualitative factors can generally be assigned to one of two categories: uncertainties that could affect the financial competitiveness of IGCC and factors external to financial analysis.

A list of investment-relevant factors beyond ROI was identified and analyzed in the December workshop sessions. This list was augmented by a search of publicly available information concerning real-world investment decisions on IGCC. The study consulted legislative proposals, such as the Energy Policy Act of 2003 (H.R. 6); government and private reports on IGCC; local regulatory documents and hearing transcripts, on projects for which IGCC was considered; news articles and opinion letters in the local press concerning proposed IGCC plants; energy companies' reports on corporate environmental performance and corporate social responsibility; and grant proposals for IGCC-relevant research.

The study examined decision notifications from decision makers, such as the Public Service Commission of Wisconsin's final order on WE Power's Elm Road/Power the Future project. The decision documents were compared against the list of factors from the workshops and literature search, to derive information on the relative importance of the factors to the decision makers.

The study team also surveyed workshop participants, asking them to rank the potential effects of different ROI uncertainties and non-ROI factors on the investment decision. The survey was first presented at the December workshop, in which the participants were primarily IGCC suppliers and government researchers. A similar survey was taken at the January workshop, in which the participants also included some potential buyer, including venture capitalists, utilities, and banking engineers. The buyer and non-buyer responses to this second survey were compared to identify differences of perspective and possible information gaps between the groups. The results of both of these surveys can be found in Appendix E.

The study's quantitative modeling assumed that a discounted financial return, such as ROI, would be the primary criterion by which investors select new generating capacity. The modeling assumed fixed values for each year for important but currently unknown variables, such as technological performance or capital costs.

Investors make their decisions under uncertainty, which makes the investment choice less clear. For example, an NGCC plant might have a very high ROI under a set of likely assumptions about future natural gas prices, but the high level of uncertainty about those prices may cause the plant investor to consider other technologies, such as IGCC.

Additional factors not explicitly modeled in the national level quantitative analysis could also influence the investment decision. For example, public power producers consider not only financial returns but also site-specific benefits, such as the use of local resources or the impacts on local employment, when choosing among technologies to meet new electricity demand.

Because ROI uncertainties and non-ROI impacts could significantly impact IGCC's market penetration potential, the study consulted with workshop participants to identify IGCC-relevant factors of these types. This list of factors was supplemented by examining regulatory and legislative hearing documents and publicly available IGCC reports. The major factors identified are shown in Table 7-1.

## 7.1. Uncertainties in the ROI Tree

A major challenge in commercializing any new technology, or a new application of an existing technology, is that scant in-use cost and performance data is available for financial analysis. For coal-based IGCC power production, the lack of

| ROI Uncertainties | |
|---|---|
| **Category** | **Factor** |
| Capital cost (Property, Plant, and Equipment (PP&E)) | Actual costs & overruns |
| | Time to operation |
| | Environmental future |
| | Capital availability |
| | NSR regs. |
| Variable cost | Natural gas prices |
| | Transportation & transmission costs |
| | Carbon capture & sequestration |
| Fixed cost | Staff costs |
| | Reliability and availability |
| Price and unit sales | Local generation capacity |

| Impacts Beyond ROI | |
|---|---|
| **Category** | **Factor** |
| National | Energy Security |
| | Environmental performance |
| | Fuel diversity |
| Local | COE |
| | Availability & reliability |
| | Jobs |
| | Use of local resources |
| | Local fuel diversity |
| | Transmission capacity |
| | Air and water impacts |
| | Land use/ NIMBY |
| | Landfill impacts |
| | Noise |
| | Negative perception of coal |

Table 7-1: Uncertainties and Non-ROI Factors Studied for Potential Impacts on IGCC Market Penetration

a large commercial track record causes uncertainty about ROI. The in-use data for commercial coal-only IGCC operations currently comes from just two plants in the United States and two in Europe.[38] Because the capacity of each these plants is approximately one-half to two-thirds of the 550 MW modeled, and because each of these plants represents a unique design, the in-use data is difficult to extrapolate to future investments. Moreover, these first-of-a-kind plants have tended to reach completion late and over cost, which has created and reinforced a reputation of riskiness among commercial generators.

This lack of operational data is one of several potential sources of uncertainty about ROI. To better identify the ROI uncertainties that might effect investment in IGCC technology, the study used an ROI tree, as shown in Figure 7-1, as an organizing aid. For each leaf of the tree, workshop participants from government and industry were asked to identify and rank the uncertainties, as well as to suggest potential approaches to mitigate some of the uncertainties. Additional information on these uncertainties was obtained through recent reports and studies.

### 7.1.1. Capital Costs (PP&E)

The level and uncertainties of capital costs—that is, PP&E—were ranked highest on a survey the study distributed. This was in agreement with the quantitative analysis, which indicated a strong influence of capital costs on market penetration. The lack of a commercial track record causes much uncertainty about IGCC capital costs.

In the opinion of several of the participants in the December workshop, pilot programs of the type typically funded by government R&D would not be very effective in mitigating this uncertainty. Typically, such projects are funded to demonstrate the feasibility and economics of a new technology or design. Investors, by contrast, desire demonstrations of repeated instances of a given technology performing within a relatively narrow, predictable band of ranges. This suggests that a standard plant design, executed several times, could effectively address this concern. Consensus estimates for the minimum number of repetitions needed was five plants. Some participants believed that substantial government subsidies and tax breaks will be necessary to get this level of investment; others believed it would just take a bold move by a private entity with confidence in their design, who would thereby gain first-to-market and learning-curve advantages.

> Refueling idle NGCC facilities with coal gasification would help reduce investment risk.

A mitigation strategy to reduce both the level and uncertainty of capital costs could be to refuel several existing natural gas plants that are now sidelined as excess capacity. Many such plants exist. In April 2003, Reuters reported that the "high cost of natural gas

38 The plants are located in Puertollano, Spain; Buggenum, Netherlands; Wabash River, Indiana; and Polk County, Florida.

and low electricity prices in the United States are keeping most of the nation's fleet of new gas-fired power plants idle because they are simply too expensive to operate."[39] Refueling could provide a relatively low capital-cost entry strategy in which a significant fraction of the capital costs—those for the existing plant—are not uncertain. This approach could also provide in-use operations data, thereby reducing other uncertainties.

Recommendation: A consistent set of standards for siting and permitting needs to be developed by Federal and state regulators.

The record of existing plants has led to a variant of capital uncertainty: a perception that construction cost overruns are endemic to IGCC. Workshop participants suggested that a "performance wrap" would be effective in mitigating this concern. Performance wraps or guarantees are critical to jumpstarting any power project because they place project risk directly on the EPC or project integrator. These entities would accept responsibility for construction cost, schedule, and plant performance risk and guarantee performance to the IGCC investor. Compared to IGCC projects, project integrators are much more willing to provide performance wraps for PC and NGCC facilites, as they are established technologies with standard plant designs. Workshop participants were not in agreement, however, about how much an up-front performance wrap should cost; whether investors could afford a performance wrap, considering the price of electricity; and whether a project could be structured to provide the certainty to allay fears of delays or overruns. Consensus was that a performance wrap could currently add as much as $100–200 to the capital cost of an IGCC plant.

Industry participants generally agreed that a performance wrap is one of the critical issues for IGCC technology acceptance by the utility sector. In the survey conducted for this study, the lack of a performance wrap was one of the top three highly rated investment factors for both the buyer and seller of IGCC technology (see Appendix E). Without performance wraps, the total development costs for IGCC will be higher and financing will be more difficult.

The time required to reach commercial operations was another capital-related uncertainty. Standard plant design could possibly reduce both the average time and the uncertainty that surround that average. More streamlined permitting procedures could reduce the average time and reduce the variance around this issue as well.

The sheer number and variety of siting issues that can be brought to a decision can create significant delays in approving and permitting an IGCC plant. These delays could continue to push back the entry into market for this technology. Since IGCC is not an established fossil energy technology, the permitting process can be extensive and perhaps contradictory. For example, there are questions as to which standard to hold IGCC, coal plants, or natural gas plants.

Actual IGCC capital costs will depend strongly on the environmental constraints under which the plant must operate. The quantitative analysis showed the extent to which discrete levels of constraints would affect IGCC market penetration. Uncertainty about the probability of each environmental scenario and of the specific level of restriction to be enacted would make the investment option more complex. Mitigation options for uncertainty include studies to reduce key uncertainties, and R&D to reduce the costs of compliance with likely emission requirements.

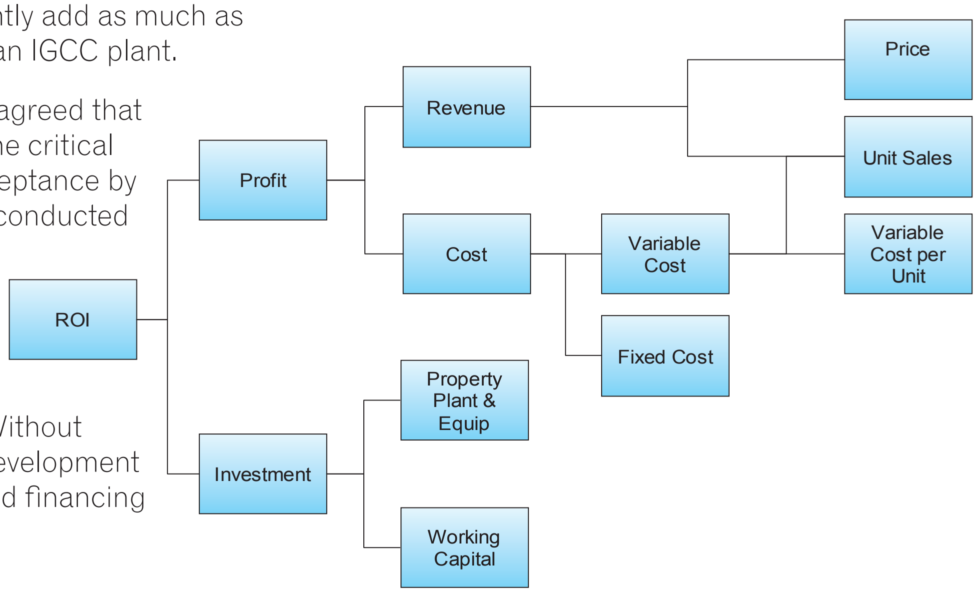



Figure 7-1: ROI Tree

[39] High U.S. gas prices idle new power plants.

The outcome of new NSR rulemaking is also currently uncertain. This could affect the capital cost of alternatives to IGCC. If a plant owner is considering modifications to an existing plant, and those modifications would trigger NSR, then the incremental cost of foregoing the modifications and re-powering with IGCC may not be very large, whereas if the modifications would not trigger NSR, then the incremental cost of IGCC may be much greater. Rapid finalization of NSR rules would mitigate this uncertainty.

Looming above the issue of capital costs themselves is uncertainty in the ability and willingness of capital markets to invest in large new generation projects. The decline of wholesale electricity prices and the large inventory of underused natural gas plants have made large-scale investment in generation more difficult to justify. IGCC is particularly sensitive to capital market conditions because its ROI justification is based on making a relatively high capital investment to achieve low and stable operating costs. Government financing assistance and innovative financing arrangements might be used to mitigate this issue somewhat, but it is a problem common to all capital-intensive electricity technologies.

### 7.1.2. Variable Cost per Unit

When considering variable costs per unit of electricity sold, the participants rated fuel prices as the factor that would be most influential to IGCC market penetration. Natural gas price volatility was highly rated as well. In the quantitative analysis, the study examined the sensitivity of IGCC penetration to natural gas price levels but not specifically to price volatility. The chair of a NPC study has reported that gas-price volatility is likely to continue in the future:

> ...recent fundamental shifts in North American natural gas markets have led to the current market conditions of higher gas prices and increased price volatility. This situation will likely persist and could deteriorate unless public policy makers act now to reduce the conflicts that are inherent in current public policies.[40]

Gas price volatility does not directly affect an IGCC plant's ROI, but rather it increases IGCC's desirability to risk-averse investors, relative to NGCC. The volatility itself (that is, the variance from smooth price curves) and the anticipated size and duration of individual price spikes were seen by the participants as disadvantageous to natural gas investment and hence relatively advantageous to IGCC. For large generators, IGCC can be a means of fuel diversification. This suggests that opportunities may exist in regions that are gas-intense and have native coal or transportation access to coal resources but are not very diversified, such as Texas.

The ability of non-conventional gas to buffer the cost and volatility of prices was questioned by the participants, and the NPC as well:

> Given the relatively low production rates from non-conventional wells, the analysis further suggests that even in a robust future price environment, industry will be challenged to maintain overall production at its current level.[41]

Historical permitting for LNG, including actions taken in the last several months, call into question the ability of LNG to meet a large portion of the United States natural gas demand smoothly and with little economic disruption. Rapid growth in the LNG port and distribution systems will require a large investment of private and public capital, may require long design and construction timelines, may exacerbate the energy security concerns of the United States, and almost certainly will entail political NIMBY siting conflicts.

Future heat rates, although important quantitatively, were not considered materially uncertain by most industry members consulted by the study. That is, a reduction in their uncertainty was not expected to significantly effect IGCC market penetration. There was general agreement among these sources that heat rates would improve steadily over time, roughly in step with the capital-cost increases.

Possible carbon capture and sequestration costs are another operating-cost uncertainty. These costs may constitute a market advantage for IGCC. NETL has reported, "While it is clear that the economics of $CO_2$ recovery are poor in all scenarios, some companies believe that they are less so for

[40] Shackouls, B.S.

[41] Balancing Natural Gas Policy (32).

gasification than for other alternatives."[42] NETL also found widespread strategic concern about carbon control strategies among stakeholders:

> One common thread about the GHG [greenhouse gas] issue that did emerge from the interviews is that nearly all the companies are giving it serious consideration as they make plans and position themselves for the future...[43]

As of 2004, no legislative proposals have suggested mandatory onsite carbon controls and most provide liberal allowances and offsets.

Fuel transportation costs and electricity transmission costs are sensitive to plant sitings. Plants relatively close to mine heads, and serviced by rail lines or barge transportation with available capacity, will have lower transportation costs than those far from coal with low available transportation capacity. Likewise, plants close to demand loads, serviced by transmission lines with available capacity, will tend to have lower transmission costs than sites far from loads with low available transmission capacity. Uncertainty in these transportation and transmission costs was not ranked highly in the expert survey as a barrier to IGCC market penetration. Mitigation would entail careful siting of plants toward areas of higher excess capacity. Policy incentives that increase the capacity and reliability of the transmission system could also mitigate this uncertainty somewhat. The impact of local shortages of transmission capacity is addressed in greater detail in the discussion of "Prices and Unit Sales."

Assess capacity and reliability of transmission systems for siting plants.

### 7.1.3. Fixed costs

Fixed operating costs were quantitatively important, but were not thought to be materially uncertain by most of the participants consulted in the study.

A few of the participants were concerned that the staff at an IGCC plant would require specialized chemical engineering skills, and that hiring or training staff with those skills might be expensive. Other members noted that specialized firms already exist that support training and startup for gasification operations, and that these firms appear to pay for themselves in cost savings to the operator.

Although not fixed costs per se, plant availability and reliability are related to this ROI element since they impact the long-term cost of operation. Survey results indicated that they were among the top four factors that could affect IGCC market penetration. IGCC availability and reliability could be considered highly uncertain because of the lack of extensive in-use data, and to the one-of-a-kind experimental nature of existing plants. Repetitions of a standard plant design would mitigate the uncertainty, and would presumably demonstrate higher in-use availability and reliability than currently seen. Data on the reliability of the gasification section of the process is currently available because of gasification's extensive use in other industries; integration of this data into credible mathematical models may provide some mitigation of reliability concerns.

Reliability data for the gasification section of the process is currently available because of gasification's extensive use in other industries; integration of this data into credible mathematical models may provide some mitigation of reliability concerns.

### 7.1.4. Price and Unit Sales

Price and demand ("unit sales" in the ROI tree) can vary widely among localities. Existing generation capacity, local demand, transmission capacity, and connectivity interact to determine the economic impact of new generation capacity, and the uncertainty that surrounds that impact. For example, the Southeast United States generally has low delivered retail electricity prices. However, if insufficient transmission capacity exists to allow significant exports of excess power, there may be few good candidate sites for a new baseload plant in this region.

Power purchasing agreements provide cautious investors with a mechanism to reduce demand and price risk for baseload IGCC plants. The feasibility of obtaining these contracts was rated among the top 10 in the study's survey of market penetration factors. The emergence of a standard market design for electricity would reduce some uncertainty about the functioning of markets, although the net effect on IGCC starts would depend on the details of the design.

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[42] Clayton, Stiegel, and Wimer, (16).

[43] Clayton, Stiegel, and Wimer, (16).

In some regulated markets, the scenario could be made to regulators that IGCC's local ancillary benefits (such as use of local coal resources, environmental benefits, and increased employment) outweigh the cost exposure that ratepayers may face. These benefits will be discussed in greater detail in the section, "Factors Beyond ROI."

Coal gasification offers flexibility in plant's products (e.g. electricity, chemicals, transportation fuels, and fertilizers). This flexibility provides investors with a means for managing product sales risk.

Product flexibility offers a potential mitigating strategy to electricity demand uncertainty: the synthesis gas (syngas) produced by an IGCC plant has value even if it is not needed immediately for electricity generation. For example, it can be used as a chemical feedstock to produce methanol, or Fischer–Tropsch "gas-to-liquid" fuels. Significant infrastructure costs may be required for storing and transporting the syngas to non-utility customers, so this mitigation comes with a cost. A related demand uncertainty is the potential emergence of a hydrogen economy, in which hydrogen is "used in combustion processes and fuel cells to provide a broad range of energy services such as lighting, mobility, heating, cooling, and cooking."[44] Because syngas can be used to generate hydrogen through a well-known chemical process (the "shift reaction"), increasing demand for hydrogen provides an alternative market for IGCC syngas. This both increases the potential revenue for an IGCC investment, and diversifies the demand for IGCC products, hence mitigating uncertainty in electric power demand.

This walk through the leaves of the ROI tree has provided a view into the range and degree of uncertainties that could affect the financial desirability, and hence the market penetration rate, of coal-fueled IGCC generation technology. Uncertainties about capital costs, variable costs per unit, fixed costs (including availability and reliability), unit sales, and electricity prices were identified and rated for market-penetration impact, and mitigating strategies were offered wherever available.

However, ROI inputs are not the only factors that could affect the adoption rate of IGCC. There are other factors, more difficult to quantify, that could go into investors' decisions. These qualitative factors are addressed in the next section.

## 7.2. Factors Beyond ROI

Even if all of the uncertainty in ROI factors could be resolved, there would still remain additional factors that could potentially influence electric-generation investment decisions. Many of these factors are difficult to quantify, or have benefits and costs that are valued differently by different stakeholders. The study analyzed these non-ROI quantitative factors through a combination of economic reasoning, expert opinion, and observation of the roles the factors have played in public debate concerning power plant technology selection and approval. Table 7-2 is a list of the factors analyzed.

| Category | Factor |
|---|---|
| National | Energy Security |
| | Environmental performance |
| | Fuel diversity |
| Local | COE |
| | Availability & reliability |
| | Jobs |
| | Use of local resources |
| | Local fuel diversity |
| | Transmission capacity |
| | Air and water impacts |
| | Land use/ NIMBY |
| | Landfill impacts |
| | Noise |
| | Negative perception of coal |

Table 7-2: Non-ROI Factors Studied for Potential Impacts on IGCC Market Penetration

### 7.2.1. Theoretical Basis

Human experience shows that decisions based on individual financial gain alone do not always lead to the highest level of benefits for all members of a society. Market failures and externalities can lead to inefficient results—situations in which at least one person could be better off without anyone else being worse off. Even for efficient outcomes, the allocation of benefits among members of a society may also be a concern. Inefficiency and inequity are problems that are often used to justify governmental intervention in real-world markets.

[44] Energy Efficiency and Renewable Energy, Hydrogen, Fuel Cells and Infrastructure Technology Program.

### 7.2.1.1. Private and Public Response to Externalities

Environmental impacts of electric power generation are generally considered negative externalities, as these emissions can affect people who do not directly benefit from the plant's operation. Power plants also have positive externalities; for example, they can provide jobs, can be a customer for local fuel resources, and can spur indirect economic growth by providing reliable source of energy to new local businesses.[45]

Analyses of externalities and market failures were historically limited to public policy debates. However, many corporations today have recognized that they have a responsibility to consider the external impacts, good and bad, that their decisions could cause. According to *The Economist*, "In a survey of the 1,500 delegates (most of them business leaders) attending the Davos meeting [2004 World Economic Forum], fewer than one in five of those responding said that profitability was the most important measure of corporate success."[46] Indeed, "Corporate Social Responsibility" is now a standard offering in many major business schools. This discipline recognizes that, even though corporations do have a fiduciary responsibility to stockholders, the corporation also has a responsibility to the society in which the stockholders live and in which the corporation operates. In reflection of this, some corporations are now issuing environmental and social supplements to their annual financial reports.

With respect to electricity generation investment decisions, social responsibility and non-financial impacts will enter into the decision process to different degrees depending on the decision makers involved, and on the nature of the communities and electricity markets in which they operate. It is reasonable to assume that direct financial considerations will dominate corporate decisions in fully unregulated markets, with increasing consideration for non-financial impacts in regulated markets, or those in which the decision maker is a public power entity or a regulator. This is illustrated in Figure 7-2. Because of this, the study focused its quantitative analysis on regulated markets. Figure 7-3 shows the status of deregulation at the state level.

### 7. 2. 1. 2. Approaches to Analyzing Hard-to-Quantify Outcomes

A major problem with analyzing social impacts, public goods, and externalities is that of measuring benefits and costs. [Kopp, Krupnick and Toman provided a comprehensive assessment of the state of the art as of the late 90s.[47]] Despite considerable theoretical and empirical work, challenges continue. A recent energy modeling workshop summarized the problem: "When there are limited or non-existent markets for socially valuable items, such as clean air, there is no market price and assigning a quantitative value is...a challenge, requiring choices among alternative methods and subjective judgments."[48]

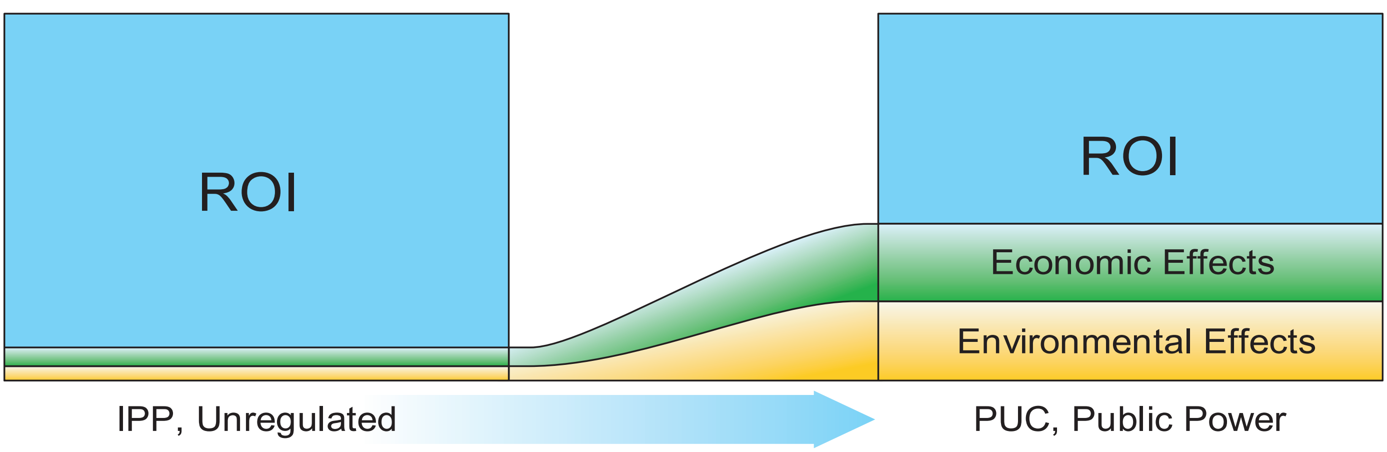


Figure 7-2: Decision Factor Weights in Unregulated vs. Regulated Markets (Illustrative)

[45] For an overview of the economics of environmental externalities with respect to power generation, Electricity Generation and Environmental Externalities: Case Studies. (Chapters 2 and 3).

[46] Two-faced Capitalism, (53).

[47] Kopp, R.J., Krupnick, A.J., & Toman, M.

[48] Electricity sector externalities.

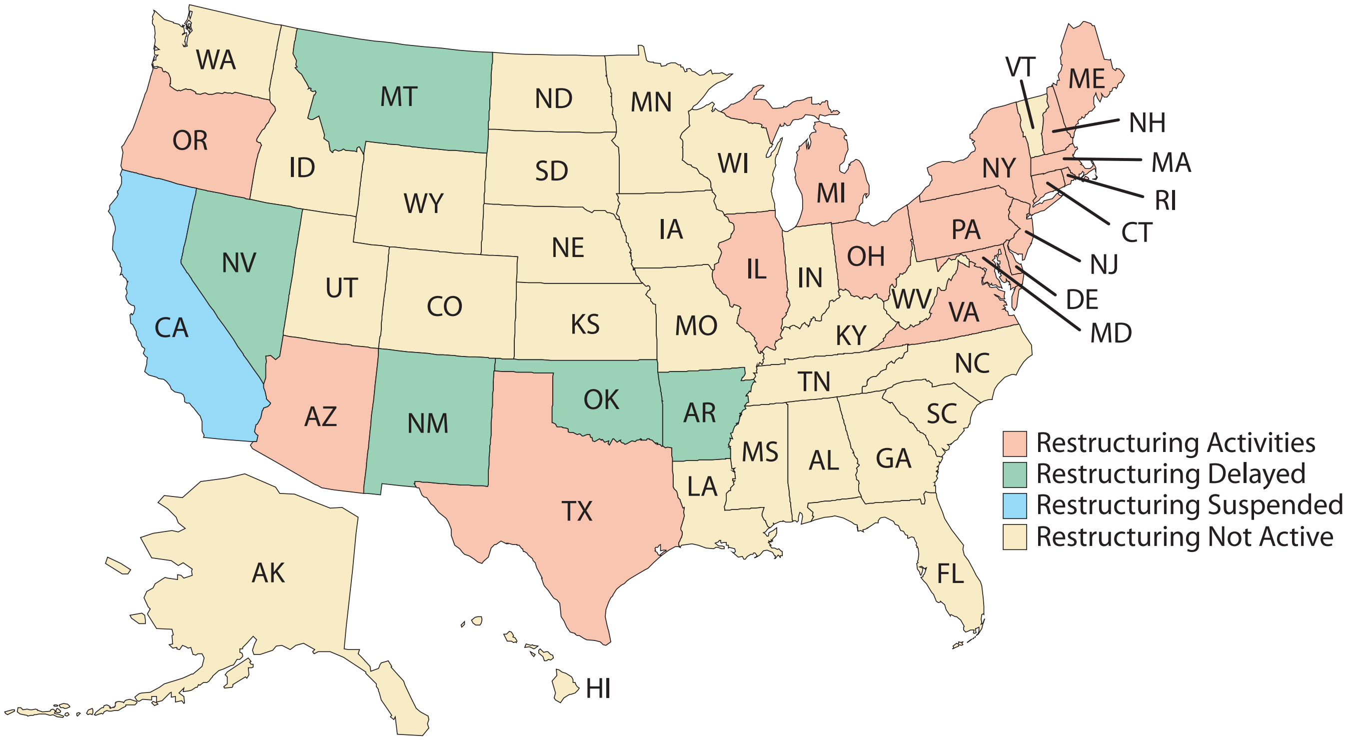


Figure 7-3: Status of State Electric Industry Restructuring (Feb 2003)

Several theoretical approaches have been used in policy analysis to deal with these difficult-to-quantify factors. One approach is to focus on impacts that can be indirectly monetized (such as the income loss and medical costs from externality-related illnesses, or recreation value of negatively impacted lands), and which can serve as a lower bound to the actual impacts. For example, the "Social Return on Investment" (SROI) methodology, developed by the non-profit Roberts Enterprise Development Fund based on work at the Stanford Graduate School of Business, falls into this category.[49] In SROI analysis, direct financial "enterprise value" is combined with a "social purpose" value to generate a "blended value." The social value includes such item as reduced social spending and increased tax revenue from project employees, but deducts any government subsidies or increased social services use.

Another standard analytic approach to dealing with these factors is to use ranges of valuation estimates derived from the literature or from expert opinion, and focus on the sensitivity of results to the assumptions. Expert-choice methods, such as decision analysis or the Analytic Hierarchy Process, are an extension of this latter approach, used in scenarios in which a specific decision needs to be made as a result of the analysis. These latter methods use expert opinion to deal with quantitative uncertainties and multi-factor preferences.[50]

The current study's approach was to identify and rate the hard-to-quantify factors through a study of public documents, press articles, expert workshops, corporate reports, and grant requests relating to IGCC projects. The relative importance of these factors was inferred from statements of decisions on projects in which IGCC was considered, wherever available; and from workshop surveys, in scenarios in which the preferences of actual decision makers were not available because of the small number of real-world IGCC projects under consideration. Factors fell into two general categories: those of concern mainly at the national level, and those that have primarily local impacts on the desirability of IGCC as a power generation investment.

### 7.2.2. National-level Factors

Although commercial IGCC investment decisions are made at the local level, there are important potential benefits to the technology that could be realized at the national level, such as energy security. Recognizing this, the Federal government has funded IGCC R&D through its Clean Coal

[49] *SROI Methodology.*

[50] See, for example, Raiffa, H. or Saaty, T.L.

programs, and has provided financial support for the construction of the two operating commercial IGCC generating plants in the United States. Changes in the level of this financial support could materially affect the market penetration rate of IGCC. If potential IGCC generation projects are designed to demonstrate support for specific federal goals, they will be more likely to win federal financial support and be built, thereby increasing IGCC's market penetration. They also could aid in sustaining public support for clean coal.

The Energy Policy Act of 2003 (H.R. 6 and S. 14, 108th Congress) initiated the most significant public debate on energy in over a decade. Title IV, Subtitles A and B of the conference bill provided support for the CCPI and clean power projects, including IGCC. The study used the bill as a source to identify and prioritize the factors that have induced national-level decision makers to provide financial incentives for IGCC development. Understanding these factors can help focus technological development in directions that support national goals, thereby encouraging additional national support, and ultimately assisting IGCC to penetrate the market.

The House version of the Energy Policy Act was titled "A bill to enhance energy conservation and R&D, to provide for security and diversity in the energy supply for the American people, and for other purposes."[51] The Senate's version was more tersely titled "to enhance the energy security of the U.S., and for other purposes."[52] Energy security appears in both titles, apparently reflecting a high priority for the administration and its supporters in Congress.

R&D programs funded by the bill were required to "advance efficiency, environmental performance, and cost competitiveness well beyond the level of technologies that are in commercial service..."[53] The bill gave gasification technical targets for $SO_2$ reduction, $NO_x$ emissions, and thermal efficiencies, as well as requiring "substantial reductions" in mercury additions. This supports the study's prior assumptions about specific environmental goals, and shows a national-level interest in balancing cost competitiveness with these goals.

To qualify for financial support, an R&D project would have to be likely to "improve the competitiveness of coal...in order to maintain a diversity of fuel choices in the United States to meet electricity generation requirements"[Section 402(d)]. Fuel diversity for electricity, then, is a national-level factor of concern that IGCC can address.

Beyond R&D projects, the bill would allow loan guarantees for private projects "to produce energy from a plant using IGCC technology of at least 400 MW in capacity that produces power at competitive rates in deregulated energy generation markets and that does not receive any subsidy (direct or indirect) from ratepayers" [Section 412]. One might imply from this that the Congress is not willing to commit to a long-term subsidy for gasification technologies to get the resulting national-level benefits of energy security and energy diversity. They appear willing to provide assistance to facilitate initial penetration, but they expect the technology to eventually be self-supporting and competitive.

The bill provides loan guarantees for an IGCC project using low-British Thermal Unit (Btu) coal "that is combined with wind and other renewable sources, minimizes and offers the potential to sequester $CO_2$ emissions, and provides a ready source of hydrogen for near-site fuel cell demonstrations." This section implies several national-level factors that IGCC might address: (1) use of lower-quality coal resources, (2) reduction in $CO_2$ emissions, (3) ability to sequester $CO_2$, and (4) development of source of hydrogen to facilitate a national hydrogen economy.

Increase awareness of IGCC's ability to use lower quality coal resources (e.g. high-sulfur coals) and to sequester $CO_2$ from coal plants.

### 7.2.3. Local-level Factors

National factors drive R&D funding and Federal financial incentives, such as loan guarantees. Local-level factors drive investment decisions on individual projects by influencing PUCs and public power entities. For local issues, the study examined PUC documents, local press articles, and the results of the GTC workshops, as well as corporate reports and grant requests. IGCC has been considered in a

[51] Energy Policy Act of 2003, (H.R. 6).

[52] Energy Policy Act of 2003, (S. 14).

[53] Conference Report on the Energy Policy Act of 2003, section 402(a).

relatively small number of scenarios, so inferences about the effects of these factors were based primarily on economic reasoning and expert opinion, confirmed with anecdotal data from the real-world scenarios.

Wisconsin Public Services Commission (WPSC), in considering the Oak Creek/Elm Road Generating Station in November 2003, had to determine if IGCC was able to "meet the standard of reasonable and in the public interest after considering alternate sources of supply, individual hardships, engineering, economic, safety, reliability, and environmental factors." In its press release on its decision, it noted,

> Many factors are taken into account when the Public Service Commission considers an application. It must balance between public interest, energy priorities and Wisconsin and federal law. This includes a variety of issues such as cost, reliability concerns, fuel diversity, energy demands and environmental impact. The Commission must also consider which technology is most feasible and energy efficient at the time it makes its decision.

### 7. 2. 3. 1. Cost of Electricity (COE)

Capital costs can impact COE in a regulated market, because the regulators typically set prices to allow generators a given ROI. One can infer that IGCC would be less attractive in regulated markets with low COE than in markets in which the COE is moderate to high. The rates required to compensate for IGCC's high capital costs would represent less of a change in existing rates for moderate-to-high COE markets, so the other public benefits of IGCC presumably could be obtained with a smaller incremental cost.

This hypothesis was difficult to test from real-world testimony. None of the states for which recent IGCC-relevant testimony is available (Illinois, Indiana, Kentucky, Ohio, Minnesota, and Wisconsin) had a COE above the national average in 2003.[54] Of these states, Illinois had the highest average COE, so it served as a proxy for a high-COE state.

In Illinois, advocates recently asked the State EPA to force Indeck Energy Services to consider IGCC instead of circulating fluidized bed (CFB) for a new coal plant in Elwood, IL. Presumably, the state's COE was sufficiently high to make arguments for other IGCC benefits relevant. The state's Lieutenant Governor stated, "Illinois tax dollars should not be used to subsidize a coal-fired plant using outdated 'fluidized bed' technology when we could be using cutting edge, 21st Century systems. Gasification is far cleaner, so sulfur emissions will be drastically cut and less mercury will end up in Illinois's rivers." In an editorial, the *Chicago Tribune* agreed, citing a long list of local public benefits:

> ...[Natural] gas is costlier than coal, its price fluctuates—and it doesn't come from Illinois.
>
> A coal gasification plant, comparable to one planned near Milwaukee for 2011, would cost roughly $1.2 billion to build, compared to $1 billion for its more conventional cousin. But its sulfur dioxide emissions would be roughly one-fifth those of a fluidized bed technology plant.
>
> Sulfur dioxide has been linked to asthma and other respiratory ailments. Emissions of nitrogen oxide, the chief ingredient of old-fashioned smog, also are considerably lower with a coal gasification plant.
>
> The Chicago area already fails some federal clean-air standards and the addition of a conventional coal plant in Joliet would make matters worse....
>
> The governor ought to press for coal gasification technology for the Joliet plant. If taxpayers are going to pony up $50 million for this venture, they deserve the cleanest air for their buck.

Indeck's arguments against IGCC did include the effect on COE, but emphasized other factors, including marginal environmental benefits and poor availability:

> ...IGCC is not commercially demonstrated. The only projects built having been built by utilities, which had substantial government funding. Demonstrated emissions between our technology, CFB, and IGCC are actually quite similar. However, IGCC availability is 20 percent lower than CFB. The capital costs are 30 percent higher. The results are—even if you could get such a project built would result in power costs 40 percent higher than with our [CFG] facility.

[54] Electric Power Monthly, (79).

#### 7. 2. 3. 2. Availability and Reliability

Availability and reliability factors have been addressed from the supplier's perspective in the section on uncertainties. These factors are also important to consumers, and hence to regulators and public power producers. WPSC explicitly noted reliability as a criterion, and Indeck declared IGCC's availability as a concern. To some extent, these reflect a national trend toward greater sensitivity to electric power reliability.

Participants in the study's workshops noted that grid reliability issues surrounding the Northeast blackout of August 14, 2003 and Hurricane Isabel in September 2003 could affect decisions regarding new power generation investments. Although these large-scale interruptions had root causes primarily in transmission grid operations, rather than local plant availability and reliability, they could heighten ratepayers' desires for reliable local generation capacity. Public power investors may increase their attention on more reliable power technologies, such as DG, over that of more conventional technologies. IGCC's perception as an unreliable technology could negatively affect its market penetration success. However, if the grid is considered unreliable by local authorities and ratepayers, there may be a greater willingness to invest in excess local baseload capacity, which IGCC could supply.

#### 7. 2. 3. 3. Jobs

The construction of a new power plant results in new jobs, both temporary and permanent. For example, Indeck stated that its proposed CFB coal plant would create 80 permanent jobs in operations, would employ 1200 union craftsmen during construction, and would create coal demand that would generate an additional 200 local mining jobs. Two Minnesota legislatures, writing about the proposed Hoyt Lakes–Mesaba IGCC plant, stated,

> The project will create more than a thousand construction jobs and hundreds of permanent, skilled jobs and attract more than $1 billion of investment to the Iron Range—an important step in reversing the economic devastation this region has experienced. The region will become a global showcase for the state-of-the-art coal gasification, or "IGCC," technology and our academic institutions will have the opportunity to attract significant federal research funds targeted toward continuing improvement of IGCC.

Although a new IGCC plant probably would not create significantly more jobs than one using another coal technology, it could do so at a lower local environmental cost. A credible chain of logic on the job advantage, then, is: power plants bring jobs; a baseload coal plant brings more jobs than an NGCC peaking plant; and an IGCC plant brings those jobs without as much environmental impact as other coal technologies.

#### 7. 2. 3. 4. Use of Local Resources

As mentioned in the uncertainties section, generating firms can reduce fuel transportation costs and uncertainties by siting their plants near to mine mouths, although these reductions may be offset by higher transmission costs. However, there is an additional benefit to this siting: local regulators and public officials may be more supportive of the plant because of the additional demand it creates for the local resource.

The *Chicago Tribune* editorial cited above referred to the benefits of an IGCC plant to coal-producing Illinois. ("...gas is costlier than coal, its price fluctuates—and it doesn't come from Illinois.") This kind of benefit would be particularly strong in states with lower grade, higher-sulfur coals because IGCC works acceptably well with these fuels and removes most sulfur prior to combustion. Note that the Wabash River plant, one of two coal-powered commercial IGCC generation plants in the United States, is located in the coal-rich state of Indiana. The proposed IGCC plant in Ashtabula, Ohio, is very close to the northern Appalachian coalfields. Coal-rich states benefit from additional demand for coal, and their regulators may therefore be more receptive to new coal-based plants, and to new technologies like IGCC that will allow continued long-term demand for coal under increasingly strict environmental constraints.

In certain situations, the polygenerating capability of IGCC could be beneficial to local resource recovery and processing. For example, the Hoyt Lakes–Mesaba IGCC plant has been proposed in the taconite (iron ore) of northern Minnesota. Taconite pellet processing requires natural gas heat for drying and pre-heating during the soft-pellet stage.[55]

[55] *Iron Ore Processing for the Blast Furnace.*

One local paper has noted that syngas could serve as a low-cost, coal-based alternative to natural gas.

### 7. 2. 3. 5. Local Fuel Diversity

The Edison Electric Institute has summarized the advantages of having a diversified portfolio of fuels from which to generate electricity: "Fuel diversity protects consumers and electric companies from fuel unavailability, price fluctuations, and changes in regulatory practices. It also helps ensure stability and reliability of our electricity supply."[56]

Coal represented approximately 35 percent of the existing generating capacity in the United States as of 2002.[57] However, coal's share of generation capacity is decreasing from approximately 42 percent of capacity to 35 percent of capacity while natural gas has increased from approximately 8 percent of capacity to 19 percent of capacity from 1991 to 2002. A large share of planned new capacity comprises of natural gas plants (see Figure 7-4).[58] Clean coal technologies like IGCC could provide to regulators and firms an environmentally acceptable means of maintaining coal's role in their diversified fuel portfolios.

Fuel diversity varies among regions. Regulators and firms in regions with a high percentage of gas generation may find clean coal technologies like

Current Transmission Adequacy Concerns

(NERC, Long-term Reliability Assessment 2003–2012, p 34.)

"In some areas the transmission grid is not adequate to transmit the output of all new generating units to their targeted markets, limiting some economy energy transactions but not adversely impacting reliability.

"Portions of the transmission systems are reaching their limits as customer demand increases and the systems are subjected to new loading patterns resulting from increased power transfers caused by market conditions and weather patterns….

"...Some well-known transmission constraints are recurring and new constraints are appearing as electricity flow patterns change as new generation is installed. As a result, the transmission system is being subjected to flows in magnitudes and directions that were not contemplated when it was designed or for which there is minimal operating experience.

"New flow patterns result in an increasing number of facilities being identified as limits to transfers, and market-based congestion management procedures and TLR [transmission loading relief] procedures are required in areas not previously subject to overloads to maintain the transmission facilities within operating limits.

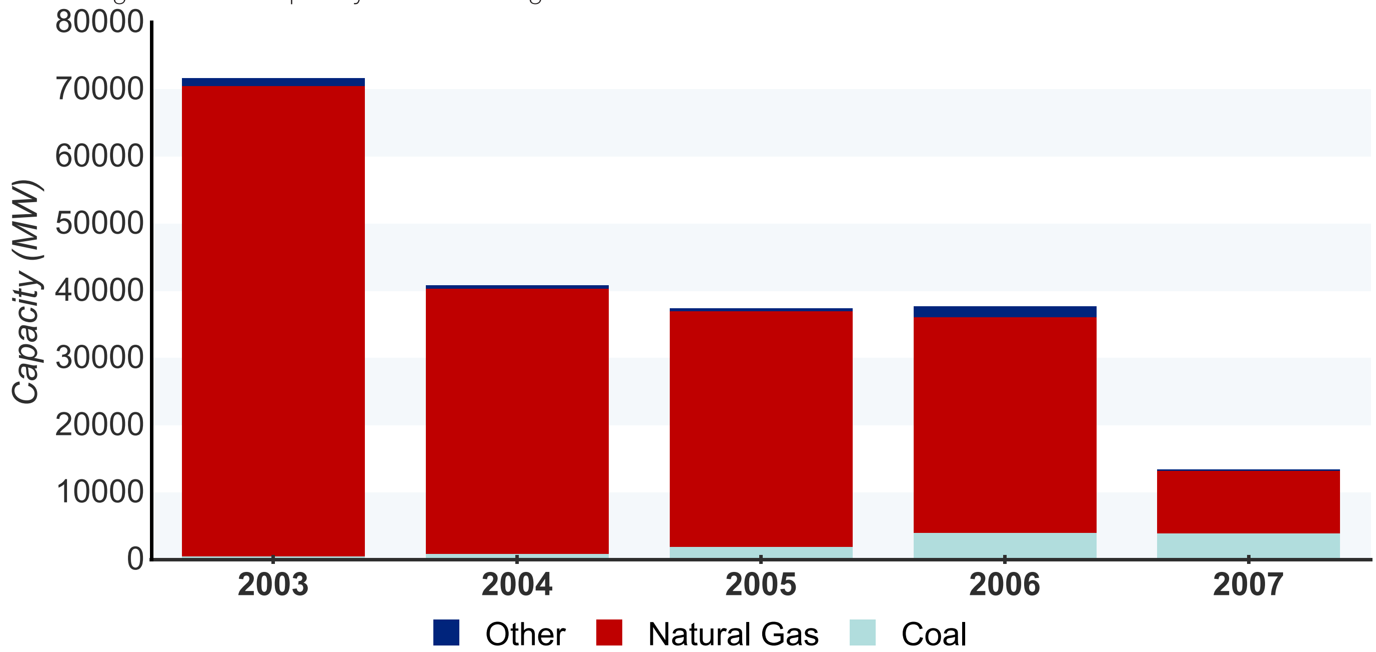


Figure 7-4: Planned Nameplate Capacity, 2003–2007
Source: EIA Electric Power Annual 2002

[56] Fuel Diversity: Key to Affordable and Reliable Electricity.

[57] *Energy Power Monthly*, (3).

[58] Recent studies indicate a resurgence of coal as a result of natural gas price volatility and trends. See, for example, *Tracking New Coal-Fired Power Plants Coal's Resurgence in Electric Power Generation*.

Advanced coal technologies, such as IGCC, provide a diversified fuel portfolio that reduces fuel cost risk.

IGCC particularly valuable from a diversity perspective. For example, the west south-central region (Texas, Oklahoma, Arkansas, and Louisiana) has a relatively large natural gas exposure, with over 45 percent of power coming from gas.[59] Firms and PUCs in this region may consider IGCC's diversification value significant enough to offset some of IGCC's higher capital costs.

### 7. 2. 3. 6. Transmission capacity impacts

IGCC plants are typically baseload plants. Consensus of the study's workshop participants was that a typical IGCC plant would have 500 MW or more of generation capacity. Firms in regions with low available transmission capacity could have difficulties getting this much additional power to market.

Potential ROI impacts of this were discussed in the uncertainty section, but there are public impacts as well. For example, some workshop participants noted that insufficient local demand could force a PUC to raise rates to obtain the ROI authorized to a new plant's investors. IGCC would clearly not be an attractive technology in markets with low excess transmission capacity and low unmet local demand. Its market penetration is likely to be faster in regions in which sufficient transmission capacity exists to bring excess capacity to external markets.

Point-to-point capacity alone is not the only transmission issue. Because of the networked nature of the grid, the addition of a large new baseload plant can affect transmission capacity far from its physical site. The relatively large capacity of the typical IGCC plant can make its impact geographically widespread. Regional transmission constraints must therefore be considered when selecting target markets for IGCC penetration.

### 7. 2. 3. 7. Air and Water Impacts

An EPRI report from 1993 stated boldly, "The single most compelling reason for utilities to consider coal gasification for electric power generation is superior environmental performance."[60] A NETL report, expanding on this, stated:

> …gasification has fundamental environmental advantages over direct coal combustion. Commercial-scale plants for both integrated gasification combined cycle (IGCC) electric power generation and chemicals applications have already successfully demonstrated these advantages. The superior environmental capabilities of coal gasification apply to all three areas of concern: air emissions, water discharges, and solid wastes….
>
> In the aggregate, the criteria pollutant emissions from a state-of-the-art IGCC plant are well-below current emissions standards for coal-fired power plants.[61]

This last characteristic—being "cleaner than it needs to be"— would probably not be highly valued in unregulated markets, although it could be considered a demonstration of corporate social responsibility. However, in regulated markets, particularly those in regions with strong environmental preferences, regulators may consider this additional cleanliness valuable enough to offset some of IGCC's higher capital costs.

Regulators in regions that are out of compliance with NAAQS, or near to non-compliance regions, may also attribute significant value to this cleaner-than-necessary performance. Figures 7-5 and 7-6 show the regions that were out of compliance for $SO_2$ and $PM_{10}$. Many of these areas are in the Northwest and Southwest, but there are also small but significant nonattainment areas in heavily populated northern Ohio, the Chicago area (Illinois and Indiana), and western Pennsylvania.

NGCC plants typically emit less of each criteria pollutant than IGCC plants per unit of energy produced, so cleanliness alone will probably not drive IGCC market penetration in and near non-compliant areas. But if coal is the fuel of choice for other reasons, IGCC's strong environmental performance may offset some of its higher capital costs relative to PC. Figure 7-7 shows the locations of coal-bearing areas in the United States. Comparing this figure with the previous two shows that IGCC's cleaner-than-required characteristics may be of particular value near the Lake Erie shoreline (northern Ohio, western Pennsylvania), around

[59] Edison Electric Institute based on EIA data.

[60] Simbeck, Korens, Biasco, Vejtosa, &. Dickenson

[61] Ratafia-Brown *et al*, (2-1, 2-2).

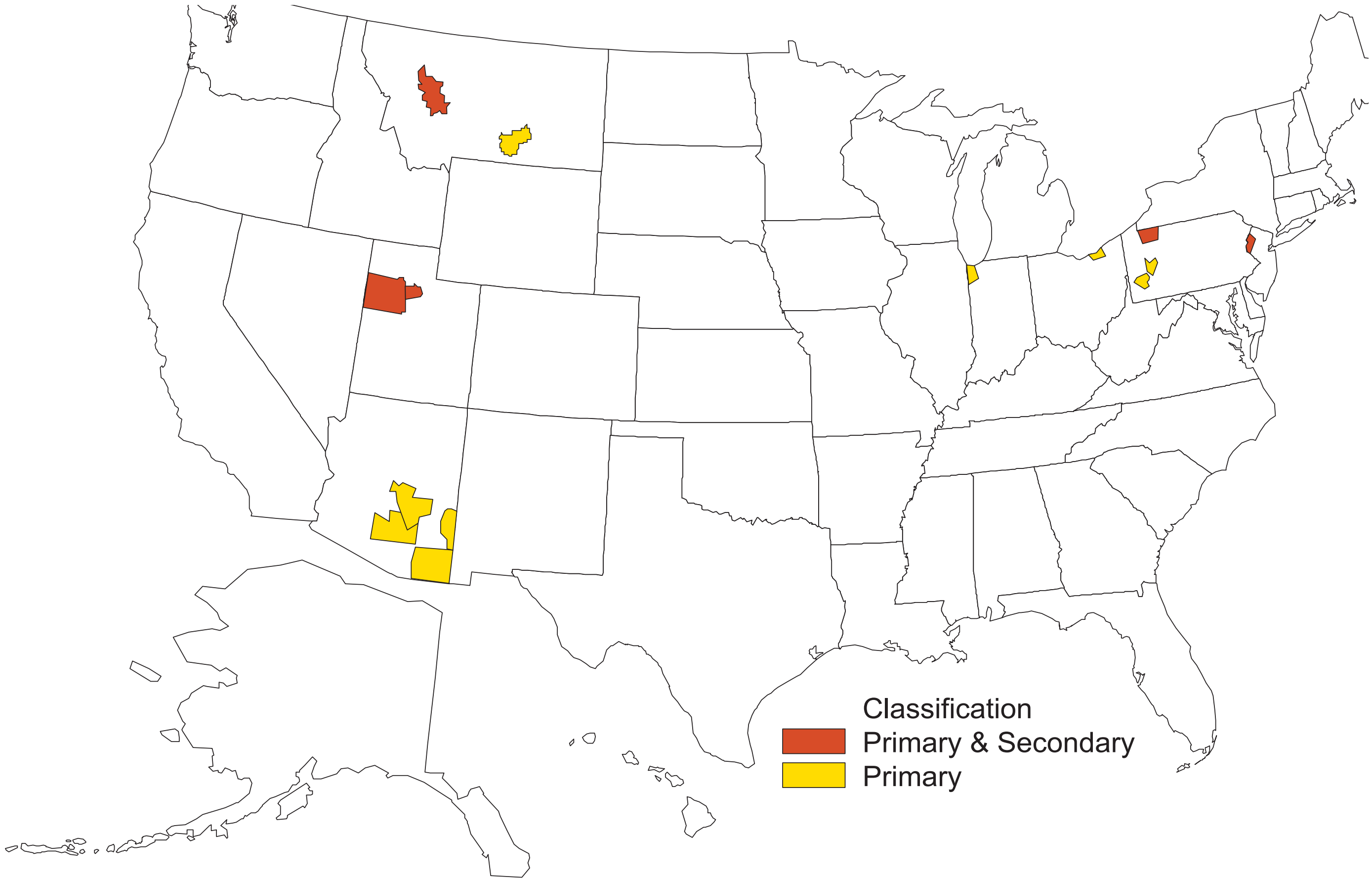


Figure 7-5: Counties Designated Nonattainment for $SO_2$

Chicago (northwest Indiana, northeast Illinois), and possibly in Montana, Utah, Arizona, and New Mexico.

Water use is a major concern in some areas of the country, such as the desert west and southwest. NETL's detailed IGCC evaluation concluded that IGCC would consume between 30 percent to 60 percent less water per unit of energy than other coal technologies.[62] IGCC will almost certainly consume more water per output than an NGCC plant because the gasification process itself consumes a considerable amount of water. Hence, the local water benefit analysis is similar to that for local air benefits: in regions in which water resources are scarce, IGCC has significant public benefit that a PUC may value, provided that there are other factors that make coal preferred to natural gas. This is discussed in more detail in Chapter 8.3.1.

The study noted that the Environmental Impact Statement (EIS) for the Wisconsin Oak Road IGCC plant did not agree with the NETL report's findings of water savings. According to the EIS, "[T]he amount of water used for once-through cooling at an IGCC facility is comparable to a conventional steam electric plant."[63] Because water on the shores of Lake Michigan is not in critically short supply, it is not likely that this discrepancy was a major decision factor in this scenario. Thorough in-use documentation of actual water savings could be important in attempting to penetrate markets in the desert west and southwest.

### 7. 2. 3. 8. Land Use/NIMBY

Greenfield power plants often generate strong public NIMBY reactions because of negative potential impacts on the immediate neighborhood. A typical EIS for a new coal plant cites a litany of potential negative local effects. For example, the WE Power Elm Road Generating Station's Final EIS addressed soil excavation and stockpiling, changes to shorelines near water intakes, fly and bottom ash, air impacts during construction and operation, noise, decreased shoreline fishing access,

[62] Ratafia-Brown *et al*, (2–5).

[63] WE Power EIS, (122).

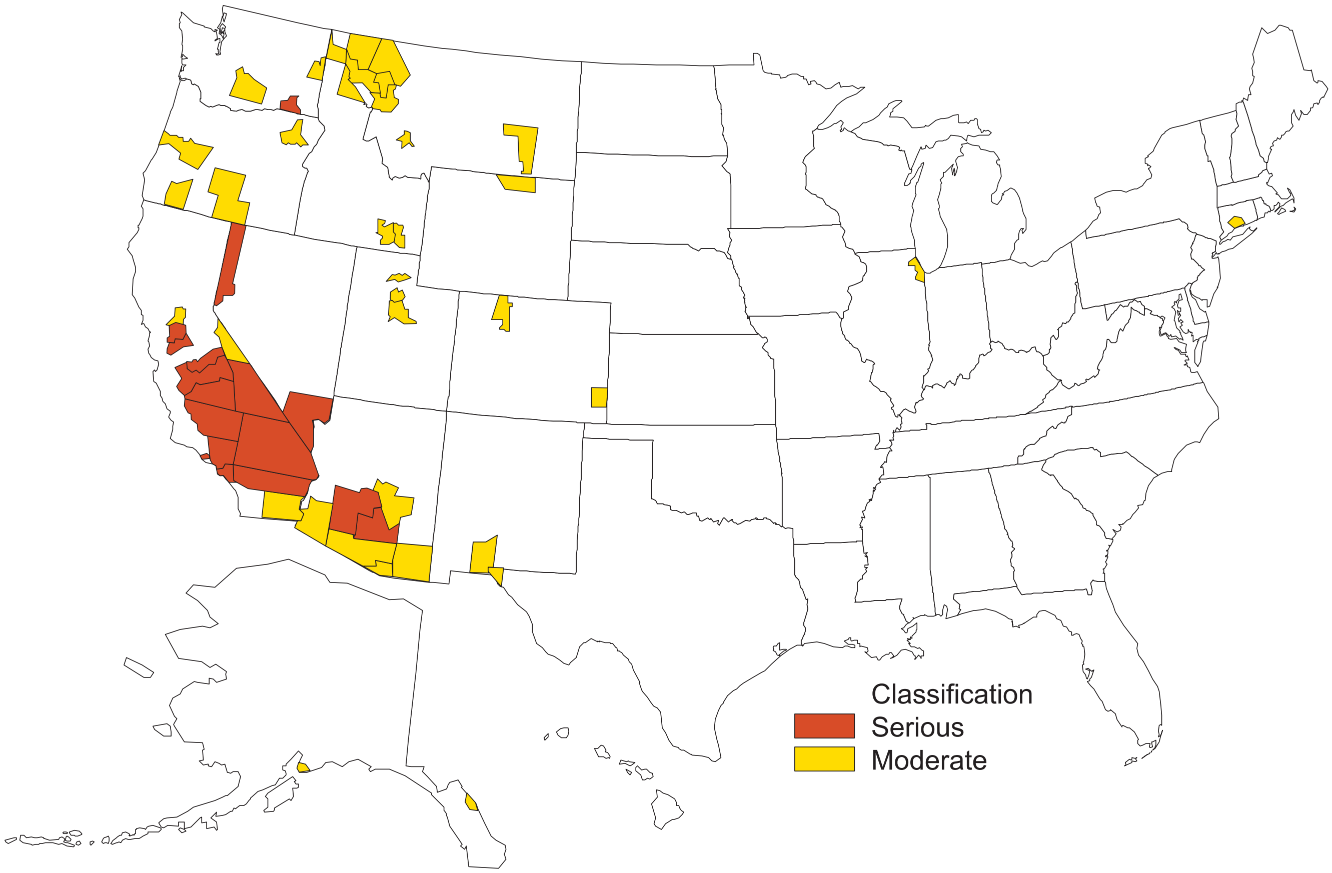


Figure 7-6: Counties Designated Nonattainment for PM-10

increased vehicular traffic, rail modifications, and loss of vegetation.[64] For IGCC plants, there may be additional concerns because of the gasification process, such as waste slag, recovered sulfuric acid, and waste-gas flaring during startup operations. Regulators and public power entities may consider these as significant costs when deciding whether to invest in a coal greenfield plant.

One approach to abating many land-use/ NIMBY concerns is to target previously used, underemployed brownfield sites. The smaller incremental impact relative to a greenfield may mitigate the land-use concerns. Several proposed IGCC plants are using this strategy. For example, the proposed site for the Hoyt Lakes, Minnesota, IGCC plant is an unused former mining site; the proposed site for the Ashtabula, Ohio, IGCC plant is an industrial site, formerly owned by Union Carbide, that has been unused for 30 years; and the proposed site for the Kentucky Pioneer IGGC plant in Trapp, Kentucky, is on a site that had previously been prepared for a coal plant that was later cancelled.

The physical footprint of an IGCC plant may exclude some existing NGCC brownfields as candidates. In the case of Xcel Energy's proposal to reduce emissions by repowering a coal plant the company considered IGCC, but proposed NGCC gas, in part because "the space required for a 500 MW IGCC plant is about 125 acres; Riverside [Site 1] is about 60 acres, while High Bridge [Site 2] is about 50 acres."[65] A brownfield market penetration strategy would have to consider the size of available sites.

The WE Power EIS raised a concern about the storage of sulfur by-products on site. In PC plants, much of the sulfur is captured after combustion, producing gypsum, a benign construction material. In IGCC, most of the sulfur is recovered during gasification, and is stored as elemental sulfur or sulfuric acid. According to the EIS, "This material may be considered hazardous waste."[66] Even though

[64] *Final Environmental Impact Statement, Elm Road Generating Station—Volume 1* (xxvi–xxxi).

[65] *In the Matter of a Petition by Xcel Energy For Approval of a Three-Plant Emissions Reduction Proposal and Rate Rider to Recover Costs.*

[66] WE Power EIS, (xxviii).

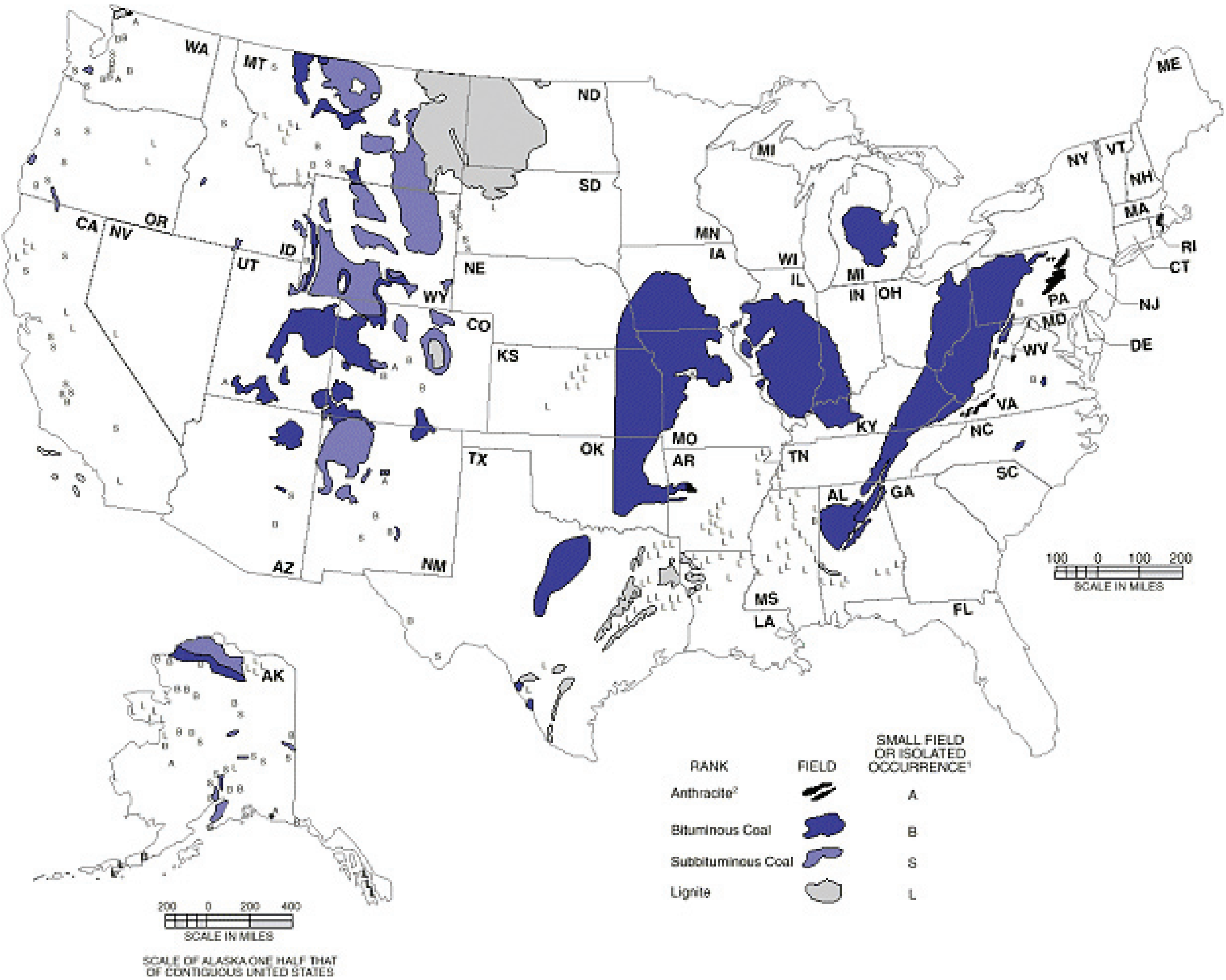


Figure 7-7: Coal-bearing Areas of the United States

this concern was not voiced in other public literature the study found, it is possible that such concerns may arise in future scenarios. Fact sheets explaining the safe handling procedures may be of some use to allay public and regulatory concerns.

According to PUC staff briefing papers for the Xcel refueling project, IGCC "resembles a refinery more than a power plant and would create zoning and land use issues."[67] The study had previously investigated the financial implications of IGCC's resemblance to a refinery; participants at the study's workshop felt that the perception would not concern private investors because there are specialized firms in the market place that provide gasification training and support gasification operations. The perception could affect regulators and public power firms, however, because of potential citizen concern about having a refinery-like addition to a coal plant.

### 7. 2. 3. 9. Landfill Impacts

In its application for the Elm Road IGCC plant, WE Power stated, "The primary advantage of IGCC is its potential for superior environmental performance, principally lower air emissions, solid waste emissions, and mercury emissions [emphasis added].[68] The NETL technical study confirms this benefit: "The IGCC plant is shown to generate significantly less total solids than the other plants, roughly one-half that of the PC plant and one-third that of the FBC plant..."[69]

[67] In the matter of a Petition by Xcel (25).

[68] Direct Testimony Of Douglas H. Cortez On Behalf Of Applicants, (5).

[69] Ratafia-Brown *et al*, (2–76).

The lower volumes of solid waste generated by IGCC provide both a private benefit (lower landfill costs) and a public benefit (extending the useful life of existing landfills). PUCs and public power companies in regions with limited landfill capacity may value these benefits enough to compensate for some capital-cost disadvantage relative to other coal technologies.

Two valuable references on Local Impacts

The Elm Road Generating Station EIS and Kentucky Pioneer EIS were two of the few available references in which IGCC was the proposed project, rather than an alternative; the proposal was sized for commercial generation using coal; and the regulatory process had reached the point of final approval or disapproval. Because of this, their community-impact sections were particularly useful in analyzing local impacts, such as land use.

As far as the potential uses for IGCC slag, the NETL report states, "Unfortunately, due to the relatively small quantities of boiler slag produced in the United States, relative to fly ash and FGD material, the markets for this type of material are not yet fully developed. There is also relatively little experience using coal gasification slag." This lack of markets and experience with slag utilization reduces the public and private benefits of IGCC's lower slag output.

### 7. 2. 3.10. Noise

The gasification section of an IGCC plant generates noise, so public decision makers may be wary of the additional noise impacts over those for NGCC.

IGCC EISs suggest that this noise difference may not be particularly large. The Kentucky Pioneer EIS notes that "noise levels inside the turbine buildings would be very high, about 155 dBA", as opposed to the gasifier building, in which the noise level is only 95 dBA. The Elm Road EIS, lacking better data, used the sound profiles of a combustion turbine power plant of similar size for its noise analysis.

A power plant or a refinery?

The WE Power EIS [page 354] shows a photograph of the gas flare at the Wabash, IN plant, and describes flare operations:

> The flare would burn waste gases from the coal gasification process. It would operate during plant start-up, which takes about two days, and it would operate during certain types of equipment malfunction.... The flame would burn from the top of a 150-foot structure. At its highest, the flame itself would be 80 feet tall, although this height would be reached shortly before the plant starts, and would only last for a few minutes. During these conditions, the top of the flame would be about 230 feet above ground level.

These suggest that operational noise differences should not be an important barrier to IGCC market entry.

### 7. 2. 3. 11. Coal's Negative Perception

Some members of the public have an unfavorable perception of coal's environmental impacts. These perceptions could negatively influence the market penetration of IGCC by influencing the plant approval process. For example, the vice-chair of the local Sierra Club chapter testified in hearings on the proposed Indeck-Elwood coal plant:

> But my question is why can't we use something besides the soft coal that's going to affect our air, our water, our fish. Why can't we use natural gas to power this plant? I also have eight grandchildren. Out of the eight, four of them have asthma. There is no other asthma in our family, just the four grandchildren, that live in Manteno out this way have asthma.[70]

An image of clean, synthetic gas from coal could provide a means for changing public perceptions of coal.

This reflects a theme that appeared frequently in the citizen testimony that the study reviewed. Coal was perceived as a dirty alternative to clean natural gas. To the extent that this impression is a factor, it could form an unnecessary barrier to IGCC market penetration. This suggests the need for developing outreach programs stressing that coal gasification provides clean gas, not coal itself, for power generation.[71]

As the above analyses show, the study found a large number of potentially relevant local factors. None appeared to represent a single dominating positive or negative value, but each (except possibly noise) represented

[70] In the Matter of Proposed Issuance of a Construction Permit/PSD Approval for Indeck–Elwood, (32–33).

[71] Some environmental advocates have recognized IGCC as an environmentally preferred source of energy from coal. See, for example, testimony by Hawkins, D.

some impact that PUCs might consider in deciding whether to invest in IGCC. Locations in regulated markets, in which one or more of the benefits are particularly relevant and valuable, represent potential entry opportunities for IGCC. If enough of these opportunities result in actual projects, this could provide the critical nucleus of operational plants that could generate the experience and data needed to give IGCC a reputation as a credible power-generation investment alternative.

## 7. 2. 4. Evidence from Decisions

The study examined several regulatory decisions on IGCC proposals to determine the degree to which the qualitative factors entered into the decision making process.

### 7. 2. 4. 1. Wisconsin PSC/WE Power

In its Elm Road decision, the PSC of Wisconsin decided "[I]t is not feasible and in the best interest of the public to build an IGCC unit at this time."[72] The narrative of the decision, and the related press release, indicate that the existing capital cost premium over SCPC was too large to justify the other benefits to Wisconsin. Estimates of existing heat rates also put IGCC at an operating-cost disadvantage.

Other items noted in the press release of the decision:

- The PSC asked Wisconsin Electric to continue to pursue IGCC technology, although it was not considered in the public interest for the particular project under consideration.
- It is unknown exactly how much it would cost to build and operate an IGCC plant because of conflicting testimony.
- There are only six IGCC units in existence in the world at this time, all of which are significantly smaller than the unit proposed by WEC.... Because the nature of this technology is relatively new and uncertain, there are unknown risks and costs in building a 600 megawatts IGCC unit at Oak Creek.[73]

Since the Wisconsin PCSC decision, industry members have since noted that the IGCC cost and performance data was mischaracterized. Industry experts contend that the data used derived from orginal capital and operating cost statistics from Wabash River and Polk IGCC facilities. These plants had undergone significant start-up issues as they were "first-of-a-kind" plants. Since then, engineering improvements have allowed these facilities and other coal gasification plants to attain high reliability and availability factors. For example, the Eastman Chemical facility in Kingsport, TN, has continued to showcase high availabilities and reliability factors. The Kingsport coal gasification plant was 98.1% available from September 2000 through September 2003 with 0.8% of the downtime as planned outage. The high availability and reliabiliity at the Kingsport coal gasification facility attributed to a long history of incremental improvements especially with regard to the coal feedstock preparation and injection.

Beyond the cost and performance data issues, local qualitative factors that would favor IGCC were not particularly relevant in Wisconsin. The COE in the state in 2003 was approximately $1/kWhr below the national average;[74] the coal to be used would have been transported from Pennsylvania;[75] fuel diversity was not an issue because Wisconsin gets approximately 50 percent of its electric power from coal;[76] and Milwaukee is in NAAQS non-attainment only for ozone, which is not a differentiating factor for IGCC.

Some factors did favor a new power plant, although not necessarily an IGCC plant. The seasonally adjusted unemployment in the Milwaukee area for December 2003 was 6.0 percent, which was above the U.S. average of 5.4.[77] The site proposed was a buffer area around the existing plant, so it had some

[72] Marquis, S.

[73] Marquis, S.

[74] Electric Power Monthly,Table 5.6.B

[75] PSCW, EIS, (xvii).

[76] Wisconsin State Profile.

[77] December Local Unemployment Rates Announced.

but not all of the advantages of a brownfield.[78] The Commission did approve two new SCPC units, but not the proposed IGCC unit.

#### 7. 2. 4. 2. Minnesota PUC/Xcel

In the Xcel repowering proposal, in which IGCC was an alternative, the Minnesota PUC staff mentioned several non-financial impacts before mentioning the cost differential. The staff reported that:

> Coal gasification technology will not work as a repowering option at existing metropolitan sites, for the following reasons:
>
> - the space required for a 500 MW IGCC plant is about 125 acres; Riverside is about 60 acres, while High Bridge is about 50 acres
> - in addition to slag (bottom ash), coal gasification produces waste syngas and elemental sulfur; the elemental sulfur would need to be stored and transported in molten form; waste syngas would need to be disposed of by combustion atop a flare tower similar to those seen at petrochemical refineries
> - capital costs for the IGCC are in the range of \$1600–\$1800/kW installed
> - compared to coal and gas-fired generating plants, IGCC is not well suited to an urban residential setting; it resembles a refinery more than a power plant and would create zoning and land use issues
> - the four commercial-scale IGCC plants operating today (two domestic, two international) have operating issues; technical issues affecting critical components remain unresolved.[79]

Subsequent documents[80] in the case do not mention IGCC as an option, suggesting that the staff's information was influential with the regulators.

At the time, Minnesota had COE even lower than Wisconsin; Minnesota produced no coal;[81] its 2002 electrical fuel mix, like Wisconsin's, was 50 percent coal;[82] as of January 2004, its seasonally adjusted unemployment was less than the national average;[83] and there were no NAAQS non-attainment areas in the state.[84]

#### 7. 2. 4. 3. Illinois/Indeck

It is interesting to note, in contrast, the arguments that Illinois officials have made to encourage the adoption of IGCC in the Indeck–Elwood case. As previously quoted, the state's Lieutenant Governor cited several non-economic advantages of IGCC:

- Reduced $SO_2$ emissions;
- Reduced Hg emissions;
- Reduced $NO_x$ emissions;
- Local resource use (coal); and
- Use of cutting-edge technology.

The COE in Illinois was the highest of the states examined (although still below the national average); the state's seasonally adjusted unemployment rate was above the national average;[85] Illinois produces on the order of 40,000 short tons of coal per year;[86] the Chicago area is non-compliant in $PM_{10}$ NAAQS, and is adjacent to an Indiana county that is non-compliant in $SO_2$.

### 7.3. Differences in Perceptions (survey)

This analysis identified qualitative factors that could be valued by local decision makers, and examined existing real-world debates and decisions to confirm

[78] PSCW, EIS, (xvii).

[79] In the Matter of a Petition by Xcel Energy, (25–26).

[80] See, for example, Xcel's Settlement Agreement Proposal, Metropolitan Emissions Reduction Proposal

[81] Coal Production Map

[82] Minnesota State Profile

[83] Minnesota Workforce Center

[84] Greenpages

[85] Illinois Dept of Employment

[86] Illinois Coal Statistics

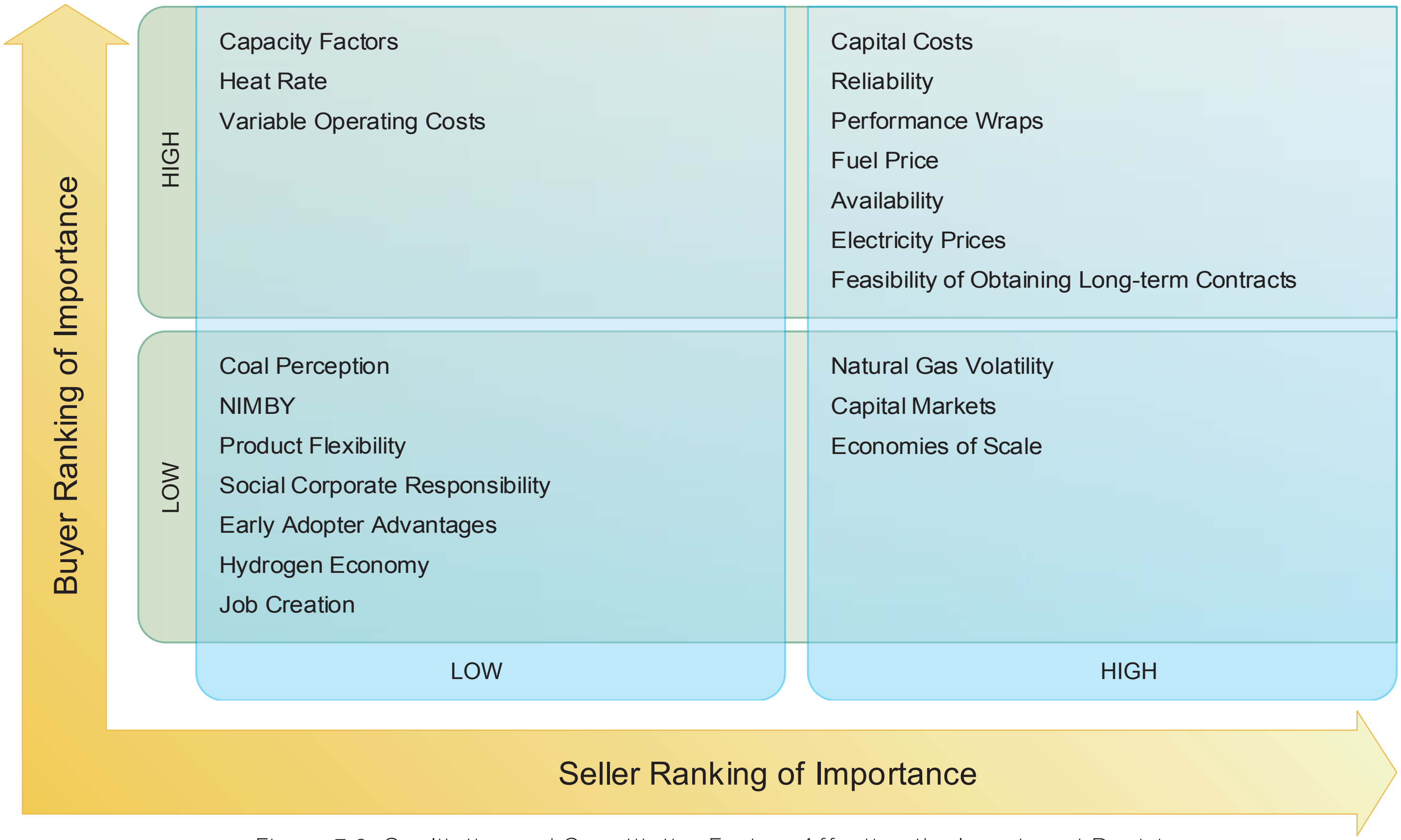


Figure 7-8: Qualitative and Quantitative Factors Affecting the Investment Decision
Buyer vs. Seller Ranking of Importance

the relevance of these factors. Information about the relative importance of these factors could not be readily derived from the few actual decisions that have been made to date. To address this challenge, the study surveyed industry and government energy experts to derive their expert opinion on the relative importance of qualitative and quantitative factors on the market penetration of IGCC technology.

The surveys measured how the different qualitative factors weighed against the qualitative factors in affecting the investment decision. Qualitative factors included site-specific issues such as NIMBY opponents and job creation, state issues such as emission levels, grid reliability, and fuel diversity, and national issues such as energy security. The quantitative factors presented in the survey represented the input variables used in the simulation modeling and the Power Pricing Modeling.

The first survey was presented at the December workshop to the study participants as a test trial. Because the participants were all technology suppliers, the survey results did not reflect the perspectives of the buyers, such as the utilities and IPPs. Participants were asked to rank on a scale of 1 to 5 how important the qualitative and quantitative factors listed affected their personal decision to invest in IGCC.

The second survey at the January workshop followed a similar format. However, this survey included a limited buyer input. The buyers at this workshop included venture capitalists, utilities, and banking engineers. This survey presented some interesting results in that some of the qualitative factors that were listed as areas of concern in earlier workshops disappeared. Figure 7-8 shows the results of this survey by ranking the buyer's rating of importance against the seller's rating of importance.

The limited number of respondents to the survey necessarily limited the statistical significance of the results. With this caveat, this study examined the results to see if they might suggest any broad trends.

Interestingly, the importance of qualitative factors such as coal perception, NIMBY, hydrogen economy, and job creation was rated low. The items ranked high by both the buyers and sellers were all financial concerns.[87] All but two of the factors listed as High/High—performance wraps and the feasibility to obtain long-term contracts—were input variables analyzed in the Power Pricing Model.

The other two quadrants in which the buyers and sellers ranked investment factors as High/Low or Low/High reveal some interesting insights. From the buyer's perspective, low variable costs and heat rates are extremely important because electricity is dispatched based on the lowest operating costs. Fixed costs and sunk capital are not factored. However, buyers are also interested in high-capacity factors because it allows them to more easily recoup sunk capital investments and fixed operating costs over time.

Other factors—natural gas volatility, capital markets willingness to invest, and economies of scale—ranked high from the seller's perspective but ranked low for buyers. For buyers, natural gas volatility or risk was not a factor. This implies that risk can be hedged in the futures market. Also, capital markets' willingness to invest was not perceived as a buyer issue. This gives the impression that there are investors willing and able to invest if the project valuation looks appealing. Potential non-traditional investors could be venture capital or hedge funds. Finally, the buyers did not consider economies of scale as a major investment factor. This result implies that larger plants with higher efficiencies are not appealing because they place more investment dollars at risk. Buyers, therefore, are willing to avoid extra capital exposure rather than achieve slightly higher efficiencies.

Altogether, the survey served as a tool to assess how strongly the qualitative aspects of an IGCC affect the investment decision. The survey conducted at the January workshop revealed that the majority of qualitative factors are not a major issue, recognizing the limited representation in the survey. Those that are, such as performance wraps and the feasibility to obtain long-term contracts, are financial in nature, and therefore are more quantitative factors.

## 7.4. Conclusions

The qualitative analysis points out several strategic lessons relevant to IGCC market penetration. These strategies can be grouped into four categories. Firms that seek to provide IGCC technology into new markets may wish to:

- Use, and encourage, federal and state programs that reduce capital costs;
- Sell in regions in which IGCC's advantages are relevant;
- Sell in localities in which IGCC's potential disadvantages are less relevant; and
- Engage in information programs on reliability and benefits.

High capital costs are perhaps the greatest obstacle to IGCC market penetration. Federal and some state governments have established incentive programs—grants, tax breaks, and loan guarantees—that can mitigate this problem. IGCC technology providers will probably want to make maximum use of these incentives, and may wish to design their offerings and proposals to demonstrate they are, in fact, providing the benefits that the governments have been investing in.

Recommendation:
Explore options for developing limited programs of loan guarantees at the Federal level to increase IGCC emergence.

All politics may not be local, but all generation projects are. IGCC providers would do well to focus their sales and marketing efforts to regions in which IGCC's advantages are particularly relevant, and to tailor projects to accentuate these advantages. These regions include those with some degree of regulation or public power, such as the Southeast, the Plains states, Kentucky, West Virginia, and Indiana; regions with a strong need for more jobs, such as the Midwest; regions that have significant underutilized coal resources, such as Appalachia; areas that have limited fuel diversity, such as Texas; regions with high or volatile natural gas prices to utilities, such as Indiana or Ohio; and regions with

Recommendation:
Target regions where IGCC's advantages are relevant will be key to successful market penetration.

[87] There were no PUC officials in the survey sample. It would be interesting to see whether the ranking would change with PUC officials and local civic leaders.

coal generation that are at or approaching non-compliance for NAAQS, such as Indiana, western Pennsylvania, and Ohio.

Areas in which IGCC's potential disadvantages are less relevant are also potential markets for IGCCs. These would be areas with a significant number of vacant brownfield sites, in which infrastructure and siting capital costs may be lower; regions with relatively high cost of electricity; locales with growing baseload demand; areas that exhibit moderate to low transmission capacity and growing native load, in which cheap grid power is not an option; or regions that have growing transmission capacity for export, in which excess power from a large new baseload plant can find markets.

Although some of the challenges to IGCC adoption are financial or technical, others are more reputation. IGCC acceptance and investment might be accelerated if current information programs on the local benefits of IGCC and the reliability of non-utility gasification were strengthened. With the potential for additional legislative and regulatory restrictions placed on utility plants, discussions of the environmental option value of IGCC with local environmental authorities could be particularly welcome, and could lead to cross-agency influence between environmental agencies and PUCs.

# Chapter Eight: Market Penetration Issues and Options

The purpose of the market penetration analysis was to find those market niches in which IGCC has the best potential for growth, considering the uncertainties that surround legislative and regulatory futures, technology advances, and natural gas prices. The market penetration analysis utilized all the results from the quantitative simulations, the power-pricing model, and the qualitative analysis for making business recommendations for IGCC. Throughout the study, the participants were constantly reminded of the anti-trust issues involved with discussing IGCC market penetration strategies. As a result, the study team solely made the recommendations in this section regarding market strategies suggestions. The role of the study participants was to inform the study team of their market knowledge without revealing any sensitive business information.

This study looked at the domestic electric generation industry in the United States. The Five-Forces analysis examines the strengths and weaknesses of the suppliers, buyers, barriers to entry, threat of substitutes, and internal competition. Assessing the forces individually and then in aggregate allows one to judge whether an industry is suitable for short and long-term profitability.

Each option was evaluated based on its SWOT under the market conditions

## 8.1. Market Attractiveness Assessment

The study team started the market penetration analysis at the June 12, 2003 brainstorming workshop. At this workshop, the study participants were asked to assess the attractiveness of the domestic electricity industry of the United States from the perspective of an IGCC investor. The study participants were made to structure their analysis by using a well-accepted market analysis framework called "Porter's Five Forces," which is illustrated in Figure 8-1.

The Five-Forces analysis rationalizes the magnitude of each force as it affects IGCC investment in the domestic electricity industry of the United States. The study team and the workshop participants assessed the forces individually and then in aggregate to judge whether the industry is suitable for a profitable IGCC investment.

For the Five F orces analysis, the study team and the participants first defined the five forces influencing the domestic electricity industry of the United States. The definitions for these forces are listed below:

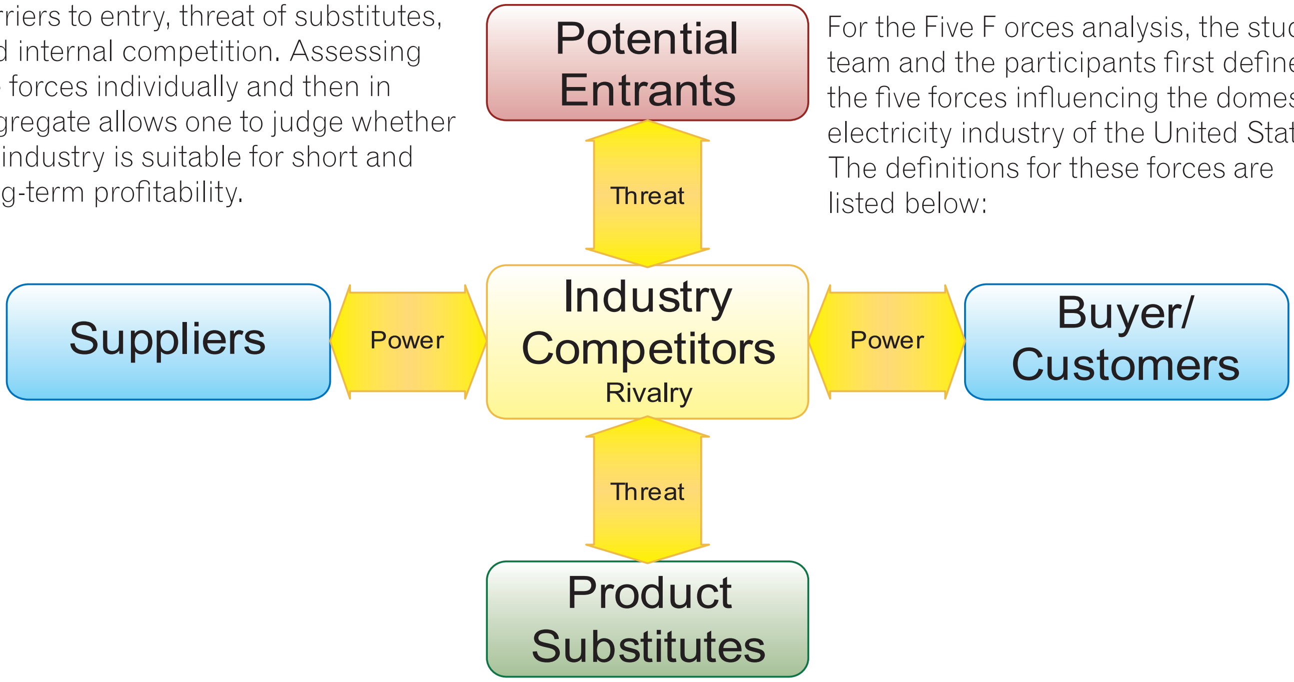


Figure 8-1: Five Forces Model[88]

[88]Grant, R. M.

- Buyers: electricity-purchasing entities such as utilities, municipalities, regional transmission organizations (RTOs), and IPPs.
- Suppliers: IGCC technology and financial suppliers such as coal mining companies, gasification technology licensors, equipment manufacturers, EPCs, labor forces, and the financial markets.
- Substitutes: energy technologies, like LNG, that could dramatically reshape the electricity market place, bulk power storage, or more productive use of the power grids for meeting load demands.
- Industry Competitors: other power technologies, such as NGCC, PC, nuclear, fuel cells, DG, and renewables.
- Barriers to Entry: those hurdles, beyond the other four forces, that IGCC must overcome to gain market entry.

Buyer power appears to be strong in the near term. Obtaining long-term power purchasing agreements in the current market is difficult because of capacity oversupply. In addition, buyers are avoiding long-term contracts, especially with new technologies like IGCC, because there are inherent fear factors in IGCC technology risk and reliability and in natural gas price uncertainty. IGCC's other option for selling is the spot market, which generally is perceived as impractical as IGCC is best suited for baseload production.

All suppliers, except for the financial markets, exhibit weak power. For instance, coal-mining companies have little pricing power because of the abundance of coal; however, this could change with consolidations among coal companies. In the current economic climate that surrounds the power industry, gasification technology licensors, equipment manufacturers, and EPC firms have weak pricing power. As gasification is adopted and the economy rebounds, these suppliers could regain pricing power. Even with some weak suppliers, the overriding supplier to IGCC is the financial market. Financial firms are hesitant in funding IGCC projects because of overcapacity, the industry's current economic slowdown, low electricity prices, and the perceived risk of the technology. Instead of using the financial markets, firms could use balance sheet funding. For most firms, this is not possible until more long-term debt is cleared.

Internal competition is intense. The two dominant competitors, natural gas and PC, have much smaller business development costs and timelines than IGCC. For natural gas, EPC firms need approximately one million dollars and only six months for development because projects are basically "cookie-cutters." They can then be constructed and in operation within two years. PC plants, however, need longer development times (one year) and have higher business development costs than natural gas plants because more engineering is required.[89] They can be online after three years of construction. IGCC plants, on the other hand, can take an order of magnitude more than natural gas plants in business development costs and two years for development. They are operational four to nine years after the business development ends. As a result, there is still uncertainty regarding IGCC business development costs and timelines.

Future substitutes present a medium concern to IGCC. LNG is viewed as both a competitor and substitute. As gas prices rise, expanding and adding LNG ports around the United States appear more likely.[90] The power grid also represents a possible short-term substitute because power providers can always pay more for electricity instead of investing in new assets. Or, the grid could be utilized better or expanded to meet demand loads more predictably and easily. Another future substitute could be cheap bulk storage. This is dependent on long-term R&D efforts.

Of all the forces, the barriers to entry characterize the largest hurdle for IGCC's market penetration. The biggest barrier is the capital cost commitment needed for an IGCC plant. Even though an 850 to 1000 MW plant is the most economical, current risk-averse financial markets are hesitant towards funding such a large investment, especially as power needs are tending toward incremental growth. The second main barrier to entry is perception. The public believes that coal is dirty; PC companies claim that IGCC is still in a research mode; investors consider the investment as too new and too risky in a saturated market; and buyers

[89] A GTC member later noted that a one-year development period might be too short for a PC-based technology.

[90] Comments later received from other GTC members argue that LNG would not be this expensive.

are uncertain about future natural gas prices (see discussion in Chapter 6). Another barrier is emission restrictions. IGCC may have to meet NGCC standards, not PC standards, for air emissions.

Market segmentation represents the division of the market into different customer types. For example, a 1000 MW plant would most certainly need to sell into the base load market and be running at high-capacity factors. Smaller plants would be used to “load follow.” Industry trends indicate that power generation is moving away from large central plants (1000–1500 MW) to scalable DG plants located closer to loads, reducing grid access and congestion issues. This stems from concerns over better reliability and energy security.

Another barrier is the critical mass of equipment suppliers necessary to attain economies of scale in IGCC plants. As demand for IGCC plants reaches a critical threshold, the limited number of equipment suppliers could make above average profits in the short term. In the long term, however, new suppliers could enter the market, thereby lowering costs.

Feedstock characteristics and plant type also could represent barriers to entry. IGCC can be constrained by location, fuel mix, and process controls. Fuel mix and coal characteristics, such as heat and ash content, play a key role in gasification location. Also, IGCC plants may have a limited capability to operate as swing plants because polygeneration facilities have slow turndown rates.

Recommendation: Develop a strategic communications plan that would guide an effective campaign to dispel the perceptions surrounding IGCC and ensure a common understanding of priorities between buyers and sellers.

Entry strategies cannot be accomplished without reducing or eliminating the forces that restrict IGCC's market penetration. For example, to remove the high capital cost barrier, IGCC units would have to be built in small, reliable increments or be provided grants or federal loans to offset perceived technology risk. A public relations campaign explaining the benefits and legacy of IGCC would also help boost this technology as public perceptions about IGCC vary significantly. Public perceptions of the technology will represent an increasing obstacle to siting IGCC. Continuing and expanding the communication of IGCC's benefits to regulators, environmentalists, and siting authorities, particularly emphasizing that IGCC produces a clean gas for combustion instead of using coal directly, may aid in shiftng public perception positively towards IGCC. Potential marketing targets include the state, the federal government, and mass media.

## 8.2. Market Penetration Strategies

After analyzing the industry characteristics, the study turned to an examination of those viable market penetration options that could exist within the industry. These market penetration strategies are defined below:

- Greenfield IGCC: building a new IGCC facility.
- IGCC with Polygeneration: building a greenfield IGCC facility that also makes chemicals, synthetic gases, or synthetic fuels.
- PC Repowering: replacing existing PC facilities that are extremely inefficient or do not meet clean air requirements with IGCC.
- NG Refueling with Syngas: adding a gasification island in front of idle NGCC assets.
- Brownfield Add-on: adding an IGCC facility in parallel to an existing PC facility.

The study also included a SWOT analysis for the SWOT of each strategy. The SWOT analysis also allowed the incorporation of the qualitative aspects of an IGCC investment as described in the previous section. These qualitative aspects include, but are not limited to, the following:

- Financial risk and investment magnitude;
- Coal perceptions, reliability concerns;
- Natural gas expectations;
- Incremental power needs;
- Regulatory uncertainty; and
- Grid interconnection.

Figure 8-2 displays the general SWOT analysis applicable to all five-market penetration options.

In the study the uniqueness of each market penetration option was examined. The first option, which was the only one simulated in the quantitative modeling efforts, is Greenfield IGCC. The chief advantage of a greenfield IGCC site over the other market penetration options is its wide acceptability. This approach to IGCC has been the most closely

| Strengths | Weaknesses |
|---|---|
| • Low-cost, stable feedstock as opposed to natural gas volatility<br>• Environmentally competitive with NGCC<br>• Ability to use other fuel sources as inputs<br>• Fewer wastes than PC plants<br>• Sequestration ready: an option value with additional equipment<br>• Multiple product output<br>• Three major players now exist | • Difficult to obtain wraps for performance guarantee<br>• No identified project integrator exists<br>• No standard design<br>• Perceived as still in an R&D mode<br>• Negative coal perceptions<br>• Reliability concerns |
| **Opportunities** | **Threats** |
| • The CCPI will create a minimum number of IGCC plants<br>• Energy bill could add possibly 1 to 2 GW of IGCC capacity<br>• Impact of mercury regulations<br>• Increased cost of natural gas<br>• Close proximity to coal resources and load demand | • Distributed generation and smaller NGCC facilities<br>• Natural gas prices fall back to historic levels<br>• Regulatory uncertainty<br>• Supplier may not be able to meet demand if there is a sudden rush for IGCC<br>• Low nuclear capital costs |

Figure 8-2: General IGCC SWOT Analysis

examined strategy and most familiar to potential buyers. The major downsides to this strategy, however, are the lack of an IGCC integrator and performance wraps. Figure 8-3 shows the SWOT analysis for Greenfield IGCC.

IGCC polygeneration is another possible entry strategy. Polygeneration is outside the scope of this study and therefore, has not been analyzed in the previous sections of the report. However, it has been identified as a potential market entry option and therefore a SWOT analysis has been done. Should such as option be explored, a more thorough quantitative analysis should be performed. Polygeneration's largest strength is its product diversification and its flexible operating structure. An IGCC polygeneration site would produce power and other products that conceivably could be varied in ratio depending on the market price and plant turndown ratio. In addition, polygeneration could provide energy storage potential as plants produce electricity at peak demands and store synthetic fuel or other products at off-peak times. The downside

| Strengths | Weaknesses |
|---|---|
| • Economies of scale<br>• A more proven technology format as compared to other entry strategies<br>• In short term, suppliers are in a weaker pricing position<br>• Most easily optimized of all options<br>• Most easily replicated of all options<br>• Future polygeneration potential | • Adversely viewed by investors because of financial size<br>• Regulatory handling of IGCC facilities relative to NGCC<br>• Reluctance to enter into long-term contracts because of uncertainty over future demand, natural gas prices, and regulatory framework |
| **Opportunities** | **Threats** |
| • Coal states that support IGCC as BACT | • Anticipated technology advancements do not occur in ASU and Gasification islands<br>• NGCC capital costs decrease at a faster rate<br>• Permitting/siting difficult because of environmental concerns and NIMBY |

Figure 8-3: Greenfield IGCC SWOT Analysis

in IGCC polygeneration is the added complexity of integrating a power facility with a chemical facility. Another drawback is that utilities and IPPs may not be interested in running a chemical facility as it is not part of their core competency. A SWOT analysis for IGCC polygeneration is shown in Figure 8-4.

> Recommendation:
> Further studying polygeneration's benefits and market applicability would help assess IGCC's role in energy.

The polygeneration concept is not a foreign one as the Dakota Gasification Company has demonstrated. The Dakota Gasification Company operates a polygeneration gasification facility capable of producing synthetic natural gas as well as fertilizers, solvents, phenol, $CO_2$ and other chemicals in varying degrees. The U.S. DOE has recognized the potential of polygeneration and has awarded WMPI, Inc., of Gilberton, PA, funding through its recent CCPI. The WMPI site will eventually produce 41 MW of power and 5,000 barrels per day of clean-burning diesel and/or jet fuel via the Fischer-Tropsch process.

PC repowering is another appealing entry strategy because it uses the existing coal facilities to lower the cost of an IGCC plant. In fact, estimates for repowering a suitable PC plant are approximately $1100/kW according to Parsons Power Group's *Advanced Technology Repowering*[91] report. PC facilities that would be applicable to repowering would be those that are extremely inefficient or do not meet clean air requirements. However, the recent NSR decision, which facilitates coal-powered facilities modifications without undergoing NSR, lessens the attractiveness of the PC repowering option. In addition, old coal-fired plants that have met their return on capital cannot economically justify an IGCC repowering unless their efficiencies are less than 15 percent according to the study team's Power Pricing Model. However, more restrictive environmental regulations could force PC plants to repower with IGCC because of the high capital costs of meeting pollution limits. Figure 8-5 shows the SWOT analysis of IGCC repowering of brownfield PC plants.

While they tend to be smaller than greenfields, repowering faces technical and locational challenges. "Site layouts are tight, electrical T&D issues can cause lengthy outages for interconnections, and the public--both citizens and regulatory bodies--wants to get deeply involved with the process."[92]

The fourth market penetration strategy examined involves refueling a NGCC plant with coal-derived syngas. Such an investment would involve adding a gasification island for syngas production to replace the natural gas that would have been used. This would cost approximately $1175/kW in overnight capital costs.  This amounts to $900/kW for the gasifier and another $275/kW for the purchase of the combined cycle, assuming that the NGCC assets could be purchased at a fifty percent discount. Clearly, this strategy has an advantage in terms

| Strengths | Weaknesses |
|---|---|
| • Flexibility to adjust production to optimize return<br>• Wider customer base<br>• Efficiency improvements because of integration with steam or syngas/ H2 host<br>• Product flexibility | • More capital intensive than a normal greenfield facility<br>• More technically complex<br>• One refinery can't use all of the H2 produced<br>• Feedstocks for most chemical facilities are ethylene-based, not gasification-based<br>• Refineries need higher reliability than currently provided |
| **Opportunities** | **Threats** |
| • Chemical facilities<br>• Oil and gas firms<br>• Agricultural products companies<br>• Large demand for $H_2$ | • Capital spending halt at major chemical companies and oil and gas firms<br>• Oversees methanol and ammonia producers producing at low prices<br>• More offshore chemical production & refining |

Figure 8-4: IGCC Polygeneration SWOT Analysis

[91] Peltier, R (30-31).

[92] Advance Technology Repowering.

| Strengths | Weaknesses |
|---|---|
| • Lower capital costs resulting from preexisting coal handling facilities and steam turbines<br>• Existing siting should facilitate permitting<br>• Much of the needed infrastructure already exists<br>• Reduced emissions on a MW-hr basis<br>• Long-term contracts likely to exist<br>• Improved efficiency of existing facility<br>• Added capacity<br>• Jobs kept; local support<br>• Political Support<br>• Wabash repowering has good supportive data | • Potential disruptions in operations<br>• Unfamiliar technology for most coal operators<br>• Would add regulatory complexity<br>• Potential for physical siting constraints |
| **Opportunities** | **Threats** |
| • Utilities needing to add capacity and increase efficiency of existing coal combustion facilities<br>• Coal sites being sued by the EPA or states for their emission levels | • New NSR ruling allows coal-powered facilities to make major modifications without triggering NSR process |

Figure 8-5: Brownfield PC Plant Repowering SWOT Analysis

of lower capital costs as compared to a greenfield IGCC plant. In addition, refueling is an appealing strategy because a power purchase contract may already exist along with transmission interconnects.

Refueling an idle NGCC plant looks particularly attractive considering the current state of the natural gas market. In the past five years, mostly merchant generation companies built more than 200,000 MW in gas-fired power plants across the United States.[93] Nonetheless, there are obstacles in finding the correct NGCC facility to refuel. For example, the idle assets may not be near rail lines or any other low-cost coal delivery method. Also, the NGCC facilities could be located in areas that have an aversion to any type of coal power generation. Figure 8-6 reviews the SWOT analysis for refueling an idle NGCC facility.

The last market penetration strategy analyzed involved adding an IGCC facility in parallel with a brownfield PC plant. Much like the PC repowering strategy, this strategy makes use of existing facilities such as the coal preparation and handling along with site support systems to lower the overnight capital costs of an IGCC facility. This strategy, although similar to the repowering strategy, has an advantage in that it would barely disrupt operations of the existing PC facility. The disadvantages are the integration of two different technologies, which could prove difficult for the operations staff. Of all the market penetration options, this one appears to be the most unlikely option. Figure 8-7 details the SWOT analysis for the add-on option.

SWOT Summary

Altogether, the best short-term options for IGCC appear to be in refueling idle NGCC assets. On the other hand, Greenfield IGCC and IGCC with polygeneration appear to be the best long-term options. These long-term strategies are even more appealing with technology advancements, higher natural gas prices, and multi-pollutant regulation. A multi-pollutant scenario also would open up many PC plants as potential IGCC candidates. Virginia lawmakers have discussed adopting a bill modeled after a “clean smokestacks” law that North Carolina passed two years ago. The bill would cut $SO_2$ emissions by 75 percent, $NO_x$ emissions by 54 percent by 2015, and mercury emissions by 67 percent by 2008. Furthermore, old, grandfathered plants would have to modernize. Like all market penetration strategies, the best one depends on what the future holds.

Recommendation: Selecting appropriate market strategy would significantly lower the costs of IGCC entering the market.

[93] S&P Issues Report on Coal-fired Electric Generation.

| Strengths | Weaknesses |
|---|---|
| • Three options: producing syngas at the plant, at a central facility and distributing, or off-site methanization<br>• Potential for producing lower-cost electricity thus allowing firm to utilize existing investment<br>• Capability to withstand natural gas price volatility<br>• Little to no disruption to operations<br>• Allows for eventual co-production<br>• Wraps are not an issue because 30% of IGCC is spent and built<br>• Lower capital investment than a greenfield site<br>• Full reliability with natural gas back up at a premium | • For a central syngas facility:<br>– NIMBYs opposed to carbon monoxide in pipelines near their communities<br>– Pipeline is expensive<br>• For all options:<br>– More capital intensive than simply leaving it as a NGCC plant<br>– Perception that coal is not as clean as natural gas<br>– There is current overcapacity in generation<br>– NSR issues<br>– Only possible at high natural gas<br>– Selling lower value product because of modifications<br>– Permitting syngas pipeline<br>• The plant loses its peaking capability<br>• Integrated aspects of IGCC lost |
| **Opportunities** | **Threats** |
| • Bankrupted NGCC assets | • Natural gas price volatility<br>• Natural gas price returning to historic levels<br>• New Source Review requirements<br>• Life extension expansion of existing coal fleet |

Figure 8-6: Refueling an Idle NGCC Plant SWOT Analysis

Of all the market penetration options, refueling is the most appealing from a cost and financial risk analysis. Results from the Power Pricing Model indicated that purchasing a bankrupted NGCC asset would improve an owner's ROI by 32 percent over the base greenfield scenario assuming the NGCC facility is purchased at a 50 percent discount. At a 25 percent discount, the ROI improves by 46 percent over the base scenario. The financial risk level improves because of the discounted purchase of the bankrupted assets and from the option of converting back to natural gas.

The refueling option has become even more attractive as more banks hold bankrupted NGCC assets. Since November 2002, at least four companies have handed over or plan on handing over fifteen merchant plants in seven states totaling 14,065 MW. Four banks would hold this capacity: Societe Generale at 6,015 MW of capacity, Citibank at 4,106 MW, French bank BNP at 3,400 MW, and Belgian bank KBC at 544 MW. In February 2004, Calpine agreed to pay $175 million in cash to ABN AMRO, a Dutch bank, for the 570 MW gas-fired Brazos Valley plant near Houston that was formerly owned by NRG Energy.[94] This translates to roughly $307/kW, which is 44 percent below the study's assumed capital cost for a new NGCC facility.

A greenfield site is also an attractive investment option as long as financial uncertainties can be offset by investor confidence or policy incentives that limit financial risk. Even though it looks appealing on paper, there are many non-investment factors that could hinder the development of a greenfield site, as addressed in the SWOT and the qualitative analyses. The refueling appears much more attractive because the siting and permitting issues are easier and the financial risk is lowered.

Repowering represents a small, yet possible market entry potential within a more intensely regulated future. A PC plant most likely would repower when the economics of installing an IGCC plant are better than installing pollution controls to meet new emission standards. The economics look attractive only when operating and efficiency losses are very high because of the added pollution controls. In

[94] Paraphrased from Banks hold 14,065 MW of merchant assets as a result of defaults by four companies.

| Strengths | Weaknesses |
|---|---|
| • Lower capital costs because of preexisting coal handling and steam turbines<br>• Existing siting should facilitate permitting<br>• Much of the needed infrastructure already exists<br>• Reduced emissions per combined output<br>• Long-term contracts are likely to exist<br>• Added capacity | • Potential disruptions in operations<br>• Unfamiliar technology to existing coal facility<br>• Would add regulatory complexity<br>• Potential for physical siting constraints |
| **Opportunities** | **Threats** |
| • Coal States with IGCC as BACT | • Capital constraints at utilities |

Figure 8-7: Add-on to Existing Coal Facility SWOT Analysis

some regulatory circumstances, added pollution controls may not be adequate to meet the emission standards, in which shutting down or repowering are the only options.

Both add-ons to existing PC plants and polygeneration market entry strategies encounter similar challenges to one another. The strategies rely on utilities or chemical companies operating outside their core competencies. For PC plants, an add-on would entail training operators to run a coal-fired boiler and a gasifier, which are two completely different processes. Chemical facilities face the same issue in that they would be operating power plants even as the trend has been the opposite. This trend may change, however, as natural gas prices continue to rise and chemical facilities begin to examine coal gasification as a viable alternative.

## 8.3. Market Selection

As discussed in Chapter 6, the qualitative aspects of the investment decision can have a significant impact on the investment decision. For example, IGCC investments may be attractive in areas in which there is a strong demand for diversified fuel sources, economic development, and/or lower power plant emissions. On the other hand, investments may not be appealing in an area in which there is difficulty in receiving a utility's permission for interconnection to the grid. Such qualitative factors are difficult to simulate but deserve close attention. To help assess the impacts of qualitative factors on market penetration, the study evaluated market penetration strategies by locational characteristics. These characteristics include state coal and water resources, electricity prices, emissions regulations, and customer type. An investor searching the market for a refueling or greenfield entry opportunity would want to consider these.

### 8.3.1. State Coal and Water Resources

State natural resources affect IGCC investment attractiveness in two ways: economic development and water constraints. From the economic development perspective, coal technologies could represent an economic boon to a state's economy, particularly within states with high sulfur coal as IGCC can handle high sulfur coals easily. Clean coal technologies, such as IGCC, help economic development in coal-rich states by creating more mining opportunities and supporting industries. IGCC also provides economic development opportunities in that it produces potential, marketable by-products such as sulfur, slag, and $CO_2$. Carbon dioxide, for examples, can be used in enhanced oil recovery. Clean coal technologies also increase economic development by increasing capacity and utilization rates of a state's infrastructure, such as roadways, railways, and rivers systems. Fifteen coal-rich states that could be amenable to clean-coal technologies because of their coal resources are listed in Figure 8-8. They are sorted in descending order of total production (thousand short tons).

These states are also represented in Figure 7-7 in Chapter 7.2. States neighboring coal-rich states might also be candidates for IGCC market penetration as long as the transportation costs are minimal compared to the coal's heating value.

Even though water withdrawal rates have increased slightly over the past five years, water usage concerns have been growing across the country and are expected to have significant impacts on future

| | Underground | | Surface | | Total | |
|---|---|---|---|---|---|---|
| States | Number of Mines | Production | Number of Mines | Production | Number of Mines | Production |
| Wyoming | 1 | 1,210 | 20 | 337,691 | 21 | 338,900 |
| West Virginia | 200 | 98,439 | 97 | 59,818 | 297 | 158,257 |
| Kentucky | 246 | 80,177 | 162 | 50,511 | 408 | 130,688 |
| Pennsylvania | 82 | 57,959 | 225 | 16,659 | 307 | 74,619 |
| Texas | - | - | 14 | 49,498 | 14 | 49,498 |
| Montana | - | - | 6 | 38,352 | 6 | 38,352 |
| Illinois | 12 | 29,642 | 6 | 3,802 | 18 | 33,444 |
| Virginia | 107 | 23,181 | 49 | 9,654 | 156 | 32,834 |
| North Dakota | - | - | 4 | 31,270 | 4 | 31,270 |
| Colorado | 8 | 19,982 | 4 | 9,155 | 12 | 29,137 |
| Indiana | 5 | 3,688 | 25 | 24,277 | 30 | 27,965 |
| New Mexico | 1 | 4 | 6 | 27,320 | 7 | 27,323 |
| Utah | 13 | 26,656 | - | - | 13 | 26,656 |
| Ohio | 9 | 11,933 | 51 | 10,336 | 60 | 22,269 |
| Alabama | 9 | 15,895 | 33 | 3,430 | 42 | 19,324 |

Figure 8-8: Coal Mining and Production Statistics by State, 2000
(thousand short tons)
Source: EIA Coal Production and Number of Mines by State and Mine Type, 2000

power plant sitings. Since 1995, total withdrawals of freshwater and saltwater have grown from 402,000 million gallons per day (Mgal/d) to 408,000 Mgal/d in 2000. Thermoelectric power in 2000 withdrew approximately 195,000 Mgal/d, or 48 percent of the water used in the United States. Illinois represented the largest withdrawer of freshwater for thermoelectric power at about 8 percent. For withdrawals of saltwater, California and Florida had the largest withdrawals for thermoelectric power at about 41 percent.[95]

Water resources constraints will factor into future power plant's locational selection. As states with water constraints would be more interested in power technologies that require less water to operate. IGCC can present a less water-intensive power option compared to PC. IGCC uses approximately 18 percent to 40 percent less water to operate than a conventional PC plant and 14 percent to 37 percent less water to operate than a fluidized bed combustion plant.[96] Moving to a dry feed gasifier would further decrease the operational water requirements.

Both coal and water resources play a critical role in IGCC market penetration strategies. A potential investor could benefit greatly by targeting those states that have vast coal resources and high water withdrawals. Table 8-1 lists the top twenty states with the highest daily fresh water and saline water withdrawal rates and represents possible targets for IGCC market penetration.

### 8.3.2. State Electricity Prices

Recommendation:
Assess IGCC's applicability to water constrained areas through additional studies.

Even though feedstocks, such as coal and water, play an important role in IGCC market penetration strategies, electricity prices may play an even greater role. As demonstrated by the results of the Power Pricing Model in Chapter 6, targeting states with high electricity prices could be part of an IGCC investor's strategy to increase ROI. Table 8-2 lists the top 20 states with the highest retail sales prices as of November 2003.

[95] Paragraph paraphrased from: Hutson, S.

[96] Ratafia-Brown, J. et al.

| State | Water withdrawals, in Mgal/d | State | Water withdrawals, in Mgal/d |
|---|---|---|---|
| California | 46,803 | Pennsylvania | 9,829 |
| Texas | 25,219 | Indiana | 9,426 |
| Idaho | 19,717 | Louisiana | 9,355 |
| New York | 18,977 | Montana | 9,316 |
| Illinois | 18,016 | Tennessee | 9,189 |
| Florida | 17,898 | Nebraska | 8,944 |
| New Jersey | 12,788 | North Carolina | 8,941 |
| Colorado | 12,714 | Oregon | 8,428 |
| Ohio | 11,668 | Alabama | 8,085 |
| Michigan | 11,628 | Washington | 7,945 |

Table 8-1: Top States in Water Withdrawals
Source: "Estimated Use of Water in the United States in 2000," U.S. Geological Survey, March 2004.

Although the retail sales prices above do not represent the wholesale price, an investor could surmise that there is a close correlation between retail and wholesale prices. Coupling the electricity prices along with the coal resources and water usage data presents potential IGCC investors with potential markets for entry.

### 8.3.3. Emissions Regulations

As noted in Chapter 7, non-attainment areas and/or states with strict emissions regulations present possible market entry points for IGCC because of its extremely low emissions as a coal technology. The map in Chapter 6 indicated there are only a few $SO_2$ non-attainment areas in which a market entry based on emission regulation is feasible. However, environmental legislation at the state level is becoming stricter and may present more opportunities for IGCC. Several Northeastern states and some Southern states, including North Carolina, have developed state-level regulations that are stricter than the Clean Air Act. North Carolina, for example, passed a "clean smokestacks" law two years ago cost the state's utilities more than $2 billion in pollution controls at 14 power plants.

### 8.3.4. Customer Analysis

The study determined that there are five different target customers for an IGCC investment. Table 8-3 lists and describes these five customer types.

Public utilities and IOUs represent the best candidates for greenfields IGCC and brownfield PC repowering. These entities, unlike the other potential customers, can better justify the higher capital costs of IGCC with the environmental benefits and economic development that it brings. In addition, public utilities have a much lower cost of capital

| State | Retail Sales Price (cents/kWhr) | State | Retail Sales Price (cents/kWhr) |
|---|---|---|---|
| Hawaii | 14.16 | Maine | 9.09 |
| New York | 11.41 | Florida | 8.01 |
| California | 11.24 | Pennsylvania | 7.91 |
| Vermont | 11.03 | Nevada | 7.52 |
| New Hampshire | 10.91 | Texas | 7.31 |
| Rhode Island | 10.72 | Colorado | 7.01 |
| Alaska | 10.57 | New Mexico | 6.73 |
| Massachusetts | 10.37 | Delaware | 6.66 |
| Connecticut | 10.15 | North Carolina | 6.64 |
| New Jersey | 9.51 | Wisconsin | 6.57 |

Table 8-2: Top Twenty States with the Highest Retail Sales Price, November 2003
Source: EIA, "Average Retail Price of Electricity to Ultimate Customers by Sector, by State, November 2003 and 2002."

| | |
|---|---|
| Public Utilities: | A public utility can be a government-owned, non-profit, co-operatively owned, or a combination of the above. Co-operatives (co-ops), municipalities (munis), and federal power marketing administrations represent three well-known types of public utilities. |
| Investor-Owned Utilities (IOUs): | An IOU is an electric utility that is privately owned, regardless of whether its shares are publicly traded or privately held. Utilities hold the exclusive or near-exclusive legal right to distribute retail electricity in a given geographic area. (In states in which deregulation has led to unbundling, some IOUs have left the generation business, and therefore would not be customers for IGCC.) |
| IPPs: | An IPP is a non-utility electricity producer that operates generation plants under the 1978 Public Utility Regulatory Policies Act (PURPA). IPPs do not possess transmission facilities and do not sell power in any retail service territory in which they have a franchise. Under the Clean Air Act Amendments of 1990, 80% or more of the electric energy generated by an IPP must be sold at wholesale. |
| Native Americans: | Some Native American governments have vast coal resources and developmental incentives that could attract IGCC investment. |
| Chemical Facilities: | U.S. producers of ammonia and ethanol could be targets for IGCC as more production moves overseas. |

Table 8-3: Potential IGCC Customers

than the other potential customers. Applying alternative financing techniques such as placing the risk on ratepayers is more easily accomplished within the jurisdiction of a PUC, making public utilities and IOUs good candidates for greenfields and repowering.

IPPs are a target market for natural gas refueling with syngas. Bankrupted assets could provide IGCC with a short-term boon. As noted earlier, at least 14,000 MW of bankrupted assets are available as possible refueling candidates. This number could increase dramatically in a few years, because IPPs that successfully refinanced their debt will have to meet their large short-term loan commitments.

The remaining two customer types represent minor customer niches. Native American investments would be the most applicable to greenfield sites if there were sufficient financial incentives and loan guarantees available. U.S. chemical facilities may be interested in coal-based IGCC with polygeneration; however, chemical facilities are hesitant of moving outside their core competencies. In addition, chemical facilities more likely would be interested in cheaper on-site petcoke or waste gas feedstocks than coal.

### 8.3.5 Market Timing

Finally, in considering market entry options strengths and weakness and locational opportunities, IGCC investors also should consider market timing. Market timing is defined as the advantages and disadvantages of first-mover versus second-mover advantage. First mover advantage represents the lead that a technology holder has by moving into the market first. The main benefits of first mover advantage are standardizing the market to a particular technology, controlling competitors from entering the market, and creating dependence on your product as a reliable and proven technology.

Being the first mover, however, can have its disadvantages such as early entry into a market before the market is willing to accept a new technology. Second movers can gain a significant advantage over first movers by capitalizing on the mistakes of previous investors. On the other hand, waiting too long could jeopardize tremendous economic gains.

Those investors who are comfortable with scenario analyses can manage market timing through simulation. Simulation modeling, such as Monte Carlo analysis, applied to scenarios across a range of potential futures can provide an investor a richer picture of IGCC's possible future. Such high-level statistical analyses will help investors better understand and mitigate the risk issues surrounding market timing.

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# Chapter Nine: Conclusions and Recommendations

Rising natural gas prices, increasingly restrictive emission requirements, and a desire for fuel diversification represent some of the reasons why power developers are reexamining their power generation portfolios. As a result, recently more inquiry has been given to clean coal technologies to alleviate these concerns. Of these, gasification is an environmentally sound method for producing electricity using the secure U.S. domestic coal resource.

## 9.1. Conclusions

This study quantitatively and qualitatively examined IGCC under a range of future scenarios that explored uncertainty in environmental constraints, technology advancements, natural gas prices, and policy incentives and found favorable outcomes in most scenarios.

### Quantitative Conclusions

Technology advances strongly affect the relative positioning of technologies. With a more aggressive advance in technology, IGCC would become the dominant coal technology in all environmental regime assumptions. These advances would also allow coal to continue to fulfill a major role in the electric power sector even in the more environmentally restrictive scenarios. *Lowering capital costs and improving availabilities through R&D are robust technology strategies for IGCC market penetration that would help ensure its success under all likely environmental scenarios.*

Environmental constraints also set the tone for IGCC penetration relative to its competitors. Under more restrictive regimes, IGCC would become the predominant coal technology, attaining maximum penetration when $SO_2$, $NO_x$, and mercury are regulated. Adding carbon constraints would negatively impact all fossil technologies. However, advances in IGCC-related technology could mitigate some of the consequences and aid its ability to penetrate the market. *Even in a scenario with significant carbon constraints, IGCC has the potential to play a continued role in our nation's electricity future. It provides the best opportunity for coal's future in a more environmentally constrained world.*

Gas prices have a secondary impact on IGCC's market penetration; they are not sole determinates. If regulations do not change appreciably from the current framework, higher natural gas prices would benefit all coal generation technologies because of their lower operating costs. *Under more constrained environmental regulations, high gas prices weaken the position of gas-fired technology but do not significantly change the relative positions of IGCC and its competitors.*

Generation-side policy incentives such as tax credits and grants could yield earlier IGCC penetration. *These incentives could be crucial to attaining the mass of successful projects needed to demonstrate that IGCC is a viable technology.* It is unlikely that the policy incentives will be tailored to solely favor IGCC. Therefore, the extent of IGCC penetration would depend to some extent on the manner in which the incentives for competing technologies would be constructed.

### Qualitative Conclusions

*Return on investment and similar financial analyses are not always the final determinant in commercial investment decisions.* This study looked at the effect of uncertainty and non-ROI factors on an IGCC investment decision and found a significant number of factors that emerge. Perceptions dominate many of these factors, when, for example, the decision body instinctively relates IGCC to the negative stereotype of coal combustion (i.e. coal is dirty) or that the technology remains unproven and in an R&D mode.

What allows these perceptions to play such a dominant role in investment decisions is the relative scarcity of operating IGCC plants in the U.S. Market entry options exist that could facilitate the early development of IGCC plants and allow actual construction and operating data to play a larger role in the investment decision. *Similarly, governmental policy incentives such as those included in the energy bill currently under consideration by the Congress, would enable market entry by reducing capital costs of the initial plants.*

*Beyond the cost and performance uncertainties, siting decisions are also affected by a host of other factors such as the region's environmental compliance status, local economic conditions, and resource proximity.* In some instances, these externalities can benefit IGCC; in others, they can be a detriment to the technology. In general, however, these issues are not found in isolation and therefore, it is the combination of factors that in whole determine whether the affect is positive or negative. This study provides a number of mitigation strategies to enhance IGCC market penetration options.

### Market Penetration Conclusions

*Of all the market characteristics, the barriers to entry represent the largest hurdle for IGCC's market penetration.* These barriers include the capital costs needed for an IGCC plant, sensitivities on coal's environmental cleanliness, perceptions that IGCC technologies are still in an R&D mode, and investment uncertainties in a possibly saturated market.

*Refueling existing NGCC assets with coal gasification, polygeneration of chemicals or fuels with power production, and repowering old PC facilities appear to have the most potential in the short-term.* Refueling is the most appealing option from a cost and financial risk analysis perspective because bankrupted NGCC assets can be purchased at a discount. The next best option could be a polygeneration site. While not within the scope of the project, polygeneration offers flexibility in products that could be attractive to integrated power and chemical manufacturers. Finally, repowering represents a small, yet possible market entry potential within a more intensely regulated future. The repowering option could factor more heavily in states that have old PC facilities and stricter air emission standards than Federal regulations.

## 9.2. Recommendations

In the overall analysis, increasing IGCC market penetration faces three challenges: overcoming financial burden relative to competing technologies; mitigating siting risks; and managing uncertainty.

### Recommendations for overcoming IGCC's financial hurdles

**Issue:** Overcoming IGCC's perceived and actual financial burdens relative to competing technologies entails continuing efforts to reduce the capital costs and improve the efficiencies of the technology. Compared to IGCC, NGCC remains relatively cheap and has low emissions for a fossil fuel. IGCC's advantage over natural gas, however, is its relatively inexpensive fuel and operating costs along with its competitive emission levels. Non-fossils, on the other hand, present a different competitive aspect for IGCC. Non-fossil's zero emissions and low operating costs (depending on the source) could pose a threat to IGCC market penetration in more restrictive environmental scenarios.

Advancing technology improvements, capitalizing on policy initiatives, and selecting the appropriate market entry strategies will help lower IGCC's financial hurdles and will offer an attractive option to competitor technologies. The following recommendations provide manners by which IGCC can lower its capital costs:

**Recommendation #1:** From the technology side, approaching R&D from both a short and long-term perspective would support earlier market penetration and overall capacity additions. In the short-term, R&D efforts that could eliminate the need for a spare gasifier, standardize plant design, increase carbon conversion rates, and/or lower the cost of $NO_x$ reduction technologies would help early penetration of IGCC technologies. A long-term R&D approach would focus more on increasing IGCC's overall market penetration through capacity additions. Particular long-term R&D efforts would include the following:

- Integrating and optimizing FB, G, and H frame turbines on syngas.
- Achieving warm-gas cleanup and high-temperature mercury control, which improves efficiency and lowers capital and operating costs.
- Replacing cryogenic ASUs with membrane separation technologies.
- Developing low-cost, highly efficient, and scalable fuel cell technologies.
- Lowering the cost of carbon controls as a hedge against the possibility of a multi-pollutant future with carbon control.

**Recommendation #2:** Selecting the appropriate market strategy would significantly lower the costs of entering the market. For example, refueling could be effective in reducing a large portion of the capital-cost uncertainty. Bankrupted assets held by large banks would be ideal as long as the asset is situated in an area applicable to coal power.

## Recommendations for managing investment uncertainty

**Issue:** The level and uncertainties of capital costs – that is, PPE – were ranked highest on a survey the study distributed to its participants. This was in agreement with the quantitative analysis, which indicated the sensitivity of capital costs on market penetration. For coal-based IGCC power production, the lack of a large, U.S. commercial track record has caused this investment uncertainty. The in-use data for commercial coal-only IGCC operations currently comes from two plants in the United States and two in Europe that are one-half to two-thirds of the 550 MW modeled. These first-of-a-kind plants have tended to reach completion late and over cost, which has created and reinforced a reputation of technology risk among potential IGCC investors. To overcome their technology risk perception of IGCC, investors desire demonstrations of repeated instances of a given technology performing within a relatively narrow, predictable band of ranges. The following recommendations offer manners by which these investment uncertainties can be more fully addressed:

**Recommendation #3:** Conduct further studies on polygeneration's benefits and market applicability to help assess gasification's role in the Nation's energy future. A longer-term strategy, such as polygeneration, could be utilized to increase gasification market penetration and reduce capital cost uncertainties. Because of its product diversification and its flexible operating structure, polygeneration could pose as a hedge against product prices and plant turndowns.

**Recommendation #4:** Explore options for developing a limited program of loan guarantees at the Federal government level may enable a sufficient number of IGCC plants to emerge. Uncertainty in capital costs has made obtaining performance guarantees or wraps difficult for IGCC investors. Loan guarantees would address the national concerns of energy security and diversity of sources in our national energy mix. The study's quantitative analysis demonstrated that these policy incentives can shorten the time for new IGCC capacity, while the qualitative analysis show that loan guarantees would help alleviate capital cost uncertainties to levels at which commercial wraps might be more readily available.

## Recommendations for mitigating siting risks

**Issue:** The siting risks confronted by a potential IGCC investor are varied, and these concerns have played a major role in IGCC related investment decisions. This role is heightened in investment decisions involving public agencies such as those found in states in which retail electricity continues to be regulated, as well as decisions involving public power, either municipals, cooperatives, or federal power marketers. Among the concerns that have been identified are the cost of electricity in a community; jobs; proximity of local resources, particularly coal; fuel diversity; transmission capacity; potential air and water impacts; landfill concerns; the NIMBY effect; and overall negative perceptions of coal. In Chapter 7 of this report, these factors are discussed and mitigation strategies are identified which can lessen these risks. Most of these strategies are locational, focusing the marketing of IGCC plants in those areas in which these factors contribute positively to the IGCC decision. The following recommendations discuss methods for mitigating these siting risks:

**Recommendation #5:** Conduct studies that assess IGCC's market applicability to specific areas. Targeting regions where IGCC's advantages are relevant will be key to successful market penetration. Regions that match well with IGCC's advantages include those with some degree of regulation or public power, a strong need for more jobs, limited fuel diversity, high or volatile natural gas prices to utilities, water constraints, foreseeable power needs, and regions with coal generation that are at or approaching non-compliance for NAAQS.

**Recommendation #6:** Additional studies assessing IGCC's applicability to water-constrained areas should be explored. A particular advantage to IGCC is its lower water requirements as compared to PC and other energy sources. Competition for available water is growing to a point where a number of power project proposals already have been impacted. Given the large amount of additional capacity projected in all scenarios to meet projected demand, this issue will likely rise in significance during the study period.

**Recommendation #7:** NETL, together with the GTC, may want to develop and implement a strategic communications plan that would guide an effective campaign to dispel the technology and coal perceptions surrounding IGCC. Public perceptions about IGCC vary significantly. The study's research indicates that even PUC staffs have significant misconceptions about the technology's reliability and advancement. Public perceptions of the technology will represent an increasing obstacle to siting IGCC. Outreach programs emphasizing that IGCC produces a clean gas for combustion instead of using coal directly may aid in shifting public perception positively towards IGCC.

**Recommendation #8:** One goal of the strategic communication plan is to establish a common understanding of priorities between buyers and sellers. In addition, the study, in its limited application, found differences among the industry representing buyers versus sellers concerning the relative importance of a number of key criteria. The issues related to different perceptions of IGCC suggest better communications are needed between IGCC proponents and their potential customers.

**Recommendation #9:** The Federal and state regulators may need to take steps to develop a consistent set of standards for siting and permitting IGCC plants. The sheer number and variety of siting issues that can be brought to a decision can create significant delays in approving and permitting an IGCC plant. These delays could continue to push back market entry for the technology. As a new and complex technology, the permitting process can be extensive and contradictory. For example, although some states are considering coal gasification as the BACT for coal fueled power generation, others are holding it to the same standards as natural gas plants.

## Final Assessment

This study answers the leading question in the Executive Summary – can IGCC play a major role in our nation's energy future? The key findings of the quantitative analysis show that IGCC can provide the Nation with a clean, reliable, inexpensive, domestic source of energy. However, a quantitative analysis alone cannot justify an investment. As the study indicates, there are qualitative factors or obstacles that may prevent IGCC from entering the market place, particularly investment uncertainties and siting risks.

The recommendations presented offer specific strategies for mitigating these qualitative factors and pushing ahead with them are critical for IGCC's initial penetration and long-term success. Altogether, these recommendations will aid IGCC in providing the United States with its energy needs at an acceptable economic and environmental cost. The future is bright, and it can be lit in part by electricity generated by IGCC.