AN ENVIRONMENTAL SUCCESS STORY: LOW-NO_X BURNERS

A quarter of the coal-fired capacity in the U.S. today uses low-NO_X burners developed through DOE investment, significantly reducing emissions of one of the chief pollutants responsible for smog and ozone buildup.

A portfolio of cost-effective NO_X-control technologies suitable for the full range of existing boilers is now available. Three major new low-NO_X burners are now widely marketed, and sales of these will reach $4 billion in the next couple of years. Gas reburning has also been successfully demonstrated on a number of different boilers, reducing NO_X by over 65%. This process breaks down NO_X into environmentally benign gases by using natural gas or finely ground micronized coal to reburn the residues of coal-firing. The Generic NO_X Control Intelligent System is the latest innovation to lead the way to the zero-NO_X plants of the future.

The costs of reducing NO_X emissions by retrofitting powerplants are now up to 90% lower than they would have been without the Federal government's research investment.

Feedwater heating is another low-cost repowering option. In this approach, heat from the exhaust of a gas turbine is used to heat feedwater for the existing boiler. The benefits are a capacity increase of up to 30% and an efficiency improvement of 5% to 10%.

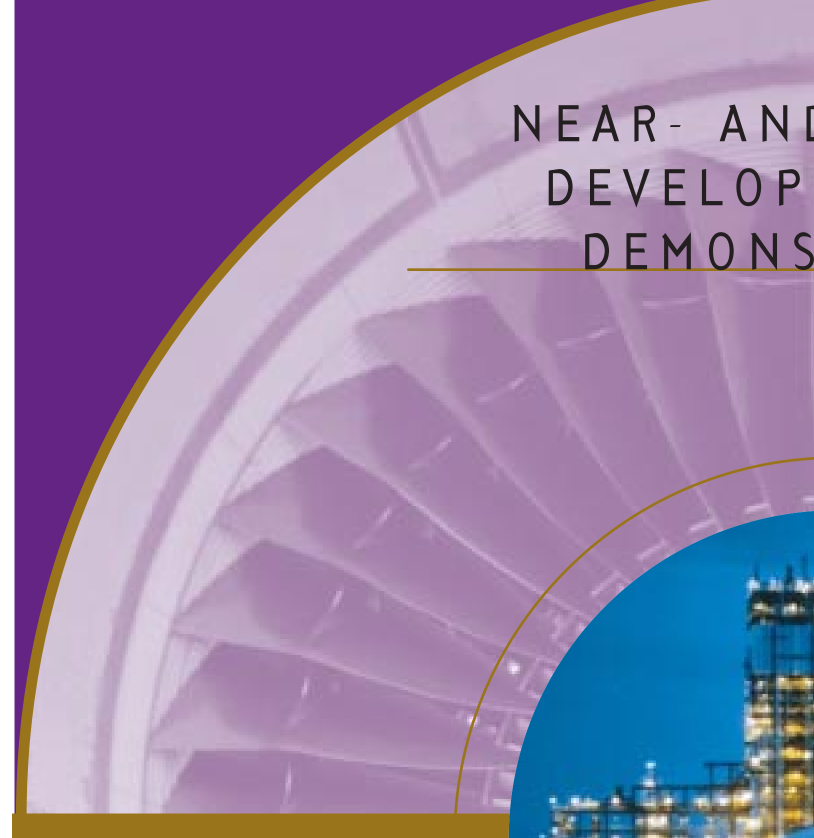
Repowering is made even more attractive because a suite of flexible advanced power system technologies developed through DOE sponsorship are available, allowing an optimum repowering strategy to be developed for site-specific situations. By repowering with clean, efficient power systems, such as a pressurized fluidized-bed combustor, integrated gasification combined cycle, or high-performance power system, net power capacity increases from 20% to 175% and net relative plant efficiency increases of over 30% can be achieved.

ADVANCED COMPUTER-BASED CONTROLS

Improving the way that existing plants are operated is an effective way to improve their environmental performance, reduce cost, and increase efficiency.

Modern control systems have significantly improved the operating performance—in terms of both cost and environmental performance—of coal-fired powerplants. However, the complexity of the optimization problem has limited the benefits achieved by conventional systems. This complexity can be overcome by embedding artificial intelligence or other advanced computer-based approaches in a powerplant's digital control system.

One of these artificial intelligence systems—the Generic NO_X Control Intelligent System (GNOCIS™)—was demonstrated at Georgia Power Company's Plant Hammond Unit 4 (a 550-MW opposed wall-fired unit), where it is fully operational and has achieved an efficiency improvement of 0.5%, a 3% reduction in the unburned carbon content of the unit's fly ash, and a 15% reduction in NO_X emissions at full load. This performance would allow a typical eastern U.S. powerplant rated at 1,000 MW to reduce its coal consumption by up to 25,000 tons per year. GNOCIS™, developed jointly by DOE, EPRI, PowerGen, Radian International, Southern Company, and the U.K. Department of Trade and Industry, is designed to operate on units burning gas, oil, or coal and is available for all combustion firing geometries. To date, 20 coal-fired plants have installed GNOCIS™. Adding these plants to the 15 powerplants that are in preliminary stages of applying this system of advanced computer-based controls suggests that by 2000 there will be 20,000 MW of power-generating capacity garnering the benefits of GNOCIS™.



NEAR- AND MID-TERM DEVELOPMENT AND DEMONSTRATION

POWER AND FUELS PRODUCTION FOR THE FUTURE

ultra-clean

ADVANCED COAL AND POWER SYSTEMS WILL ENABLE CLEANER, MORE EFFICIENT USE OF DOMESTIC FOSSIL ENERGY RESOURCES FOR GENERATING LOW-COST ELECTRICITY AND PRODUCING LIQUID AND SOLID FUELS, AND CHEMICALS.

ultra-efficient

PROGRAM AREAS

Clean Coal Technology Demonstrations

- Advanced Electric Power Generation
- Environmental Control Devices
- Coal Processing for Clean Fuels
- Industrial Applications

Power Systems

- Advanced Turbine Systems (ATS)
- Low-Emissions Boiler System (LEBS)
- High-Performance Power Systems (HIPPS)
- Fluidized-Bed Combustion (FBC)
- Integrated Gasification Combined Cycle (IGCC)

Fuels

- Transportation Fuels
- Solid Fuels and Feedstocks

INTRODUCTION

RESPONDING TO NEW MARKETPLACE REALITIES

DOE programs developing coal and power systems are responding to dramatic changes occurring in the energy marketplace. Energy industry deregulation could create intense cost-reduction pressures on power producers; DOE programs are geared to provide these producers with cost-competitive solutions to environmental challenges. At the same time, gas, electric, and oil companies are merging into larger business entities that are investing less in research. Therefore, DOE programs must leverage limited private-sector research dollars more effectively than ever. Deregulation is also creating new markets for energy products, like Vision 21 plant concepts that will use gas, coal, and biomass fuels to generate a mix of products that include electricity, liquid fuels, and chemicals, with virtually zero environmental impact.

STRATEGIES FOR SUCCESS

Specific strategies for the near- and mid-term development and demonstration program are to:

- Conclude commercial-scale demonstration projects in the Clean Coal Technology (CCT) Demonstration Program by 2005.
- Perform technology readiness and full-scale testing for two alternative natural-gas utility-scale Advanced Turbine System (ATS) concepts by 2002.
- Demonstrate proof-of-concept for a low-emission boiler system (LEBS), advanced pulverized-coal-fired powerplant by 2003.
- Develop high-performance power system (HIPPS) designs for large commercial plants, prototype plants, and repowering applications.
- Remove technological limitations on hot-gas filtration to achieve the full performance potential of fluidized-bed combustion (FBC) plant designs by 2002.
- Extend the superior environmental performance of integrated gasification combined-cycle (IGCC) systems beyond electric power generation to production of market-based energy and chemical products.
- Reduce the cost of producing coal-derived transportation fuels from $30 to $21 per barrel.
- Enable coproduction of power, liquid fuels, and premium carbon products from coal and fuels containing biomass or solid waste.

These strategies are yielding measurable benefits to the U.S. economy and environment. As the CCT program is being completed, for example, it is making readily available to industry a compendium of operational, technical, environmental, and economic performance data and experience on advanced, highly efficient fossil power technologies. The results will demonstrate to developers and users that these advanced power technologies provide benefits that far outweigh the risks often associated with new technology investments.

The U.S. will also realize economic benefits from exporting clean energy technologies resulting from DOE programs. International opportunities for advanced fossil energy technology exports are enormous. It is estimated that the annual worldwide demand for energy will reach 542 quadrillion Btu by 2015, 1.6 times the current level. Coal is expected to account for about 25% of this demand. The total worldwide market for new powerplants will be approximately $2 trillion between 2000 and 2030. The U.S. has the potential of capturing a large portion of this market—more than $480 billion in revenues, supporting 600,000 U.S. jobs over three decades.

Programs to produce liquid fuels from coal could also yield substantial economic and energy security benefits. Increasing production of liquid fuels by 1 million barrels per day using liquefaction technologies would reduce our Nation's balance of payments by $130 billion between 2015 and 2030.

A domestic industry based on converting coal into 2 million barrels per day of liquid fuels would provide, by 2030, more than 660,000 high-paying jobs in coal mining, manufacturing, and management, as well as jobs in indirect supporting labor, and would attract as much as $100 billion in new investments. Further, coal-derived fuels could "cap" imported oil prices. A $1 savings in the price per barrel of oil could yield a $6-billion-per-year benefit to our economy.

Coal-derived liquid transportation fuels provide significant environmental benefits. Fuels such as Fischer-Tropsch diesel or dimethyl-ether-derived diesel could enable the design of modified diesel engines with improved efficiencies and up to 47% reduction in emissions.

CLEAN COAL TECHNOLOGY DEMONSTRATION PROGRAM

The Clean Coal Technology Demonstration Program was implemented through a series of five nationwide competitive solicitations conducted over a 10-year period. The first solicitation selected technologies to balance the goals of expanding coal use and minimizing environmental impact. The next two solicitations favored technologies to mitigate potential impacts of acid rain from existing coal-fired powerplants. The fourth and fifth solicitations addressed post-2000 energy supply-and-demand issues: the capping of sulfur dioxide (SO_2) emissions in the Clean Air Act Amendments of 1990, the increased need for electric power, and the need to alleviate concerns over global climate change.

Now that more than half of the resulting projects have been completed, the value of the program is clear.

PERFORMANCE OF NEAR- AND MID-TERM COAL AND POWER TECHNOLOGIES

		Cost Performance			Environmental Performance			
Program Area	**Target Year**	**COE** [Note 1]	**Capital** [Note 2]	**Efficiency** [Note 3]	**SO_X** [Note 4]	**NO_X** [Note 4]	**CO_2** [Note 5]	**Particulate** [Note 6]
ATS (gas)	2002	10% lower	10% lower	60% (LHV)		<10 ppm	67% less	
LEBS	2002	10% lower	lower	45%	0.1	0.1	23% less	0.01
HIPPS	2008	20% lower	10% lower	55%	0.06	0.06	36% less	0.003
FBC	2008	$0.045	$950	52%	0.06	0.06	33% less	0.003
IGCC	2008	$0.045	$1000	52%	0.06	0.06	33% less	0.01

Notes
1—Cost of electricity (COE) in $ per kilowatt-hour. Lower refers to comparison with today's technology.
2—Capital cost in $ per kilowatt. Lower refers to comparison with today's technology.
3—Efficiency based on higher heating value unless noted otherwise.
4—Values as pounds-per-million Btu unless noted otherwise.
5—Reduction of CO_2 emitted compared to a 35% efficient coal plant.
6—Particulates as pounds-per-million Btu unless noted otherwise.

BENEFITS TO THE NATION

Economic security. A major benefit of near- and mid-term power technologies is low-cost electricity for citizens and industries. Because electricity expense is a major factor in the cost of providing products and services, sustaining a low-electricity production cost is critical for U.S. industry's competitiveness in the world market. Energy technology provides the foundation for competitive alternatives needed to meet varying marketplace situations.

Reduced balance-of-trade deficit. Because U.S. industry is de-emphasizing longer-term research as part of short-term survival strategies, federally sponsored technology development is critical to sustaining U.S. industry's competitiveness in the world marketplace. Energy technologies being developed address rapidly expanding global-market demands and are, therefore, central to U.S. responsiveness to export opportunities that translate into high-paying U.S. jobs.

Energy security. Providing technologies that use our abundant indigenous resources as a significant component of our Nation's fuel mix is critical to maintaining energy independence and security.

Environmental acceptability. These technologies offer the means to produce energy from abundant, low-cost fossil fuels without detriment to the environment.

Lower carbon dioxide emissions. Because of high-efficiency energy conversion, these advanced technologies will greatly reduce the release of carbon dioxide into the atmosphere as they replace less efficient technologies.

Results are benefiting existing plants as well as next-generation systems. Today, for example, NO_X reduction technologies demonstrated through CCT projects are being retrofitted to over 25% of the Nation's coal-fired capacity. These technologies can achieve not only existing regulated emissions levels, but also those proposed by the Environmental Protection Agency (EPA) for 2000. The program has also demonstrated several advanced technologies that have significantly improved the economic and environmental performance of SO_2 controls.

Furthermore, CCT technologies are being used to transform low-rank and noncompliance coals to useful, environmentally superior coal-based fuels for use by domestic utility and industrial coal users, and are being considered for major projects abroad. In addition, coal-based industrial processes are gaining significant environmental and economic benefit from the demonstration of these advanced technologies.

New power generation systems validated through the program include circulating fluidized-bed technology, pressurized fluidized-bed combustion (PFBC), and integrated gasification combined-cycle systems. These systems are now in or near commercial-scale operations that demonstrate their strong potential as electric power generation and coproduction plants of the next century.

The Clean Coal Technology Demonstration Program reached a significant milestone in 1997 with the completion of 21 of 39 active projects. Several demonstrated technologies, including fluidized-bed and gasification technology, are now being successfully commercialized.

CCT PROJECTS

Number of Projects	Market Segment	Number Completed
11	Advanced Electric Power Generation	2
19	Environmental Control Devices	15
5	Coal Processing for Clean Fuels	2
4	Industrial Applications	2

DEVELOPMENT AND DEMONSTRATION

ADVANCED ELECTRIC POWER GENERATION

Approximately 56%, or about $3.2 billion, of total available government CCT funds has been earmarked for advanced electric power generation systems, to enhance their efficiency, environmental performance, and reliability. Over 900 megawatts (MW) of new capacity and over 800 MW of repowered capacity are represented by 11 advanced electric power generation projects. Projects include four IGCC systems, five PFBC or circulating fluidized-bed combustion (CFBC) systems, and two advanced combustion / heat-engine systems. These projects will provide environmentally sound, more efficient, and less costly electric power generation, while providing a demonstrated technology base necessary to meet new capacity requirements in the 21st century.

ENVIRONMENTAL CONTROL DEVICES

Valued at more than $700 million, 19 environmental-control projects include seven NO_X emissions-control systems installed on over 1,700 MW of utility-generating capacity, five SO_2 emissions-control systems installed on about 770 MW, and seven combined SO_2 / NO_X emissions-control systems installed on about 700 MW of capacity. The operating experience of most of these environmental-control devices was documented by the end of 1997.

COAL PROCESSING FOR CLEAN FUELS

Five projects that create clean fuels by coal-processing, valued at nearly $520 million, represent a diversified portfolio of technologies. Three of them involve the production of high-energy-density solid compliance fuels for utility or industrial boilers; one also produces a liquid for use as a chemical feedstock. One project is demonstrating a new methanol production process. Another has developed an expert computer software system that enables a utility to predict the operating performance of coals not previously burned in its boiler.

INDUSTRIAL APPLICATIONS

Four projects with industrial applications have a combined value of nearly $1.3 billion. They include the substitution of coal for 40% of the coke used in iron making, integration of a direct iron-making process with the production of electricity, reduction of cement kiln emissions and solid-waste generation, and demonstration of an efficient, industrial-scale combustor.

FIVE POWERPLANT AWARDS PRESENTED TO CCT PROJECTS BY *POWER MAGAZINE*

- Tidd PFBC Demonstration Project (The Ohio Power Company) – 1991
- Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.) – 1993
- Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.) – 1994
- Wabash River Coal Gasification Repowering Project (CINergy Corp/PSI Energy Inc.) – 1996
- Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company) – 1997

POWER SYSTEMS IN THE MID-TERM

- By 2002, technology readiness and validation testing will be performed for two competing natural gas utility-scale advanced turbine system generation concepts.
- By 2003, proof-of-concept will be demonstrated for a LEBS advanced pulverized-coal-fired powerplant.
- By 2002, technological limitations on hot-gas filtration will be solved to achieve the full performance potential of FBC plant designs.
- By 2010, DOE will run a pioneer coproduction IGCC plant and, by 2015, a full-scale plant will deliver market-based energy and chemical products that cost less than those from any other sources.

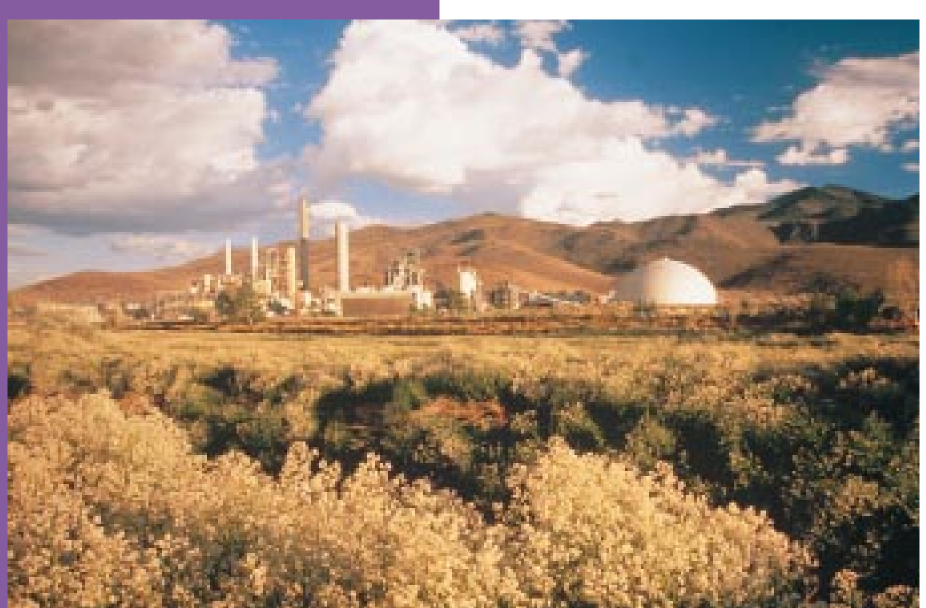
POWER SYSTEMS

A key strategic goal of the Office of Fossil Energy is to develop progressively higher-efficiency power systems. In the long term, these systems are to produce near-zero levels of pollutants while simultaneously reducing electricity costs by 10% to 20%. Several advanced systems are near completion:

The ***Advanced Turbine Systems (ATS)*** program is close to commercializing a prototype utility gas turbine with remarkable improvements in efficiency and environmental performance. Over the next two years, testing will be completed for full-scale components and subsystems, as will manufacturing capability for the first test engines. Site preparation will begin for critical full-speed engine tests scheduled for the final phase of this program.

The ***Low-Emissions Boiler System (LEBS)*** is in its final phase. An 80-MW proof-of-concept facility, scheduled to be on-line in 2001, will reduce SO_2 and NO_X to less than one-sixth the levels required under New Source Performance Standards (NSPS). Incorporating supercritical boiler technology, the design will boost thermal efficiencies to 42% compared with today's 33% to 35%. More than 73% of the final phase's $127 million costs will be provided by the private sector and State government.

High-Performance Power Systems (HIPPS) are based on the indirectly fired combined cycle, a cycle that is particularly attractive because of its very high thermal efficiency and capability to handle a wide range of fuels, including "opportunity" fuels (such as petroleum coke or sawdust) and "wastes." Efficiencies of 47% to 50% can be achieved with gas turbines available today. With turbines expected to be available when HIPPS is deployed in about a decade, efficiencies of 55% will be possible.



The third IGCC plant to become operational in the United States, the 100-MW Sierra Pacific Piñon Pine project near Reno, Nevada, demonstrates a KRW air-blown gasifier with in-bed sulfur capture, advanced hot-gas cleanup, and General Electric power generation. With an anticipated efficiency of over 43%, the plant will deliver more efficient, less costly, and cleaner electricity.

Pressurized Fluidized-Bed Combustion (PFBC) technology moves coal combustion to a new plateau of performance with efficiencies for initial systems approaching 45%, and SO_2 and NO_X removals at levels one-fifth that required under the NSPS. Improvements could raise efficiencies to more than 55% and emission levels to one-tenth the NSPS limits.

Integrated Gasification Combined Cycle (IGCC) is a key system in the Vision 21 plant concept. The goal is to improve efficiencies, costs, and environmental performance for power, fuels, and chemical production.

ADVANCED TURBINE SYSTEMS

The DOE Office of Fossil Energy (FE) and the Office of Energy Efficiency and Renewable Energy (EE) share responsibility with industrial partners for developing advanced turbine systems. FE supports the utility-scale system development, industry/university consortium, materials research for advanced alloys, ATS applications for coal fuels, and the Federal Energy Technology Center (FETC) in-house R&D. EE supports the industrial-scale system development, materials research on thermal barrier coatings, ceramic retrofit engine development, and ATS applications for biomass fuels.

Program benefits include (1) commercialization of utility-scale ATS concepts as the cleanest, most efficient combined-cycle powerplant available by 2002; (2) reduced cost of electricity to consumers, thereby preserving competitiveness of U.S. industry in world markets; (3) sustained U.S. global technology leadership; and (4) major reductions in NO_X and CO_2 emissions.

UTILITY-SCALE ATS PERFORMANCE
60% (LHV) system efficiency
<10 ppm NO_X emissions
10% reduction in cost of electricity
Reliability, availability, and maintainability of current combined-cycle products

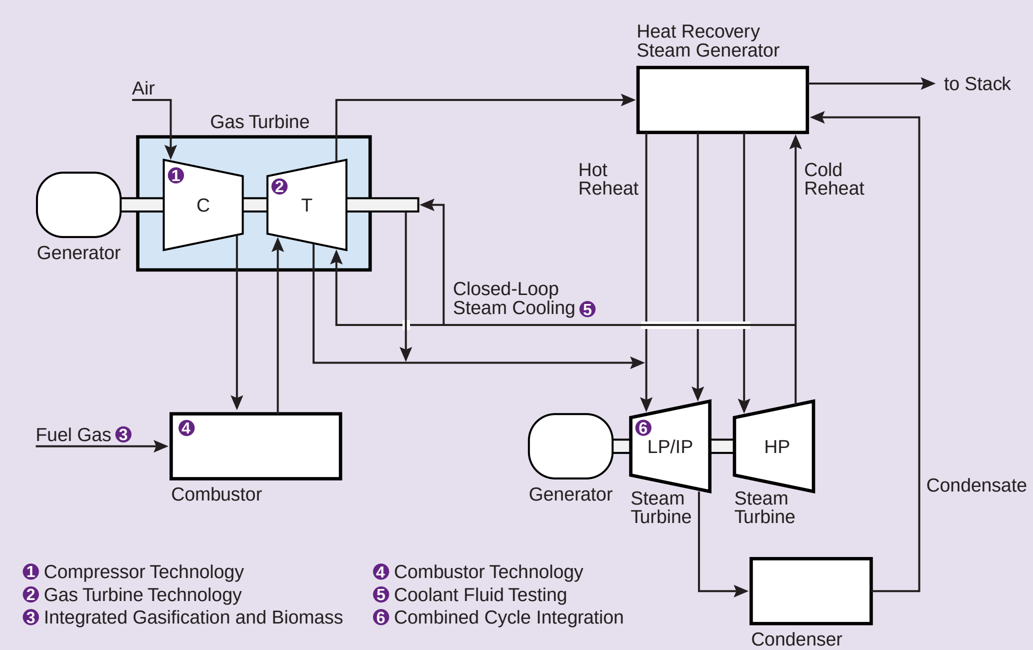
Utility-scale ATS

Utility-scale ATS concepts are being developed by General Electric Company and Westinghouse Electric Corporation.* Both will complete evaluation of their combustion, heat transfer, and aerodynamic design concepts under actual operating conditions by December 2000.

* *Westinghouse Electric Corporation was purchased by Siemens on August 20, 1998, and was renamed Siemens Westinghouse Power Corporation.*

UTILITY ADVANCED GAS TURBINE SYSTEMS

Outstanding environmental performance and improved economics in both natural-gas-fired and coal-fired applications are promised by advanced turbine systems. In the near term, natural gas will play an increasing role in electric generation. Natural-gas units are more efficient and less capital-intensive, have lower non-fuel costs, are more rapidly constructed, and remain economical in small sizes. However, in the mid-term, advanced coal systems will replace or reduce natural-gas feed as gas systems become relatively more expensive than coal.



General Electric Company. General Electric is conducting compressor tests for the 7H ATS system. The compressor is the first stage of the turbine and increases the pressure of large volumes of air needed for combustion of natural gas or other fuels. High-temperature tests have verified effective cooling of hot turbine components by steam to achieve ATS turbine temperatures.

Casting of the largest advanced single-crystal turbine components in the world was also completed, a critical step toward commercializing the ATS gas turbine. Single-crystal materials, much stronger than the polycrystalline materials now used to produce blades, are better able to resist conditions present in the ATS. Technology development for the H program has already yielded many side benefits to U.S. industry. Turbine component development, which deals with manufacturing turbine blades, has improved with the use of advanced processes for casting complex, single-crystal metallurgical turbine parts.

Westinghouse Electric Corporation. Westinghouse has introduced the 501G ATS gas turbine, featuring an aerodynamic design incorporating the latest computer models and turbine-component design. Use of a computer model has resulted in reduced turbine component thickness and increased efficiency without increased manufacturing costs.

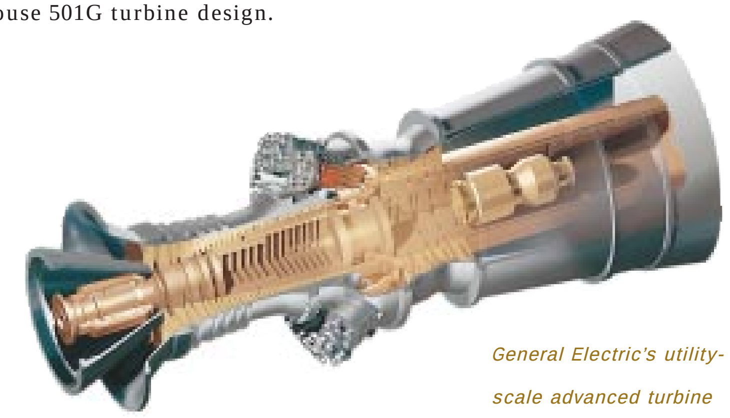
The piloted-ring combustor is a lean, premixed, multistage design that produces ultra-low pollutant emissions while maintaining stable turbine operation.

To solve efficiency losses caused by leakage around the ATS internal parts, Westinghouse has developed brush and abradable coating seals for the stationary sections of the turbine. These seals have already been incorporated into the Westinghouse 501G turbine design.

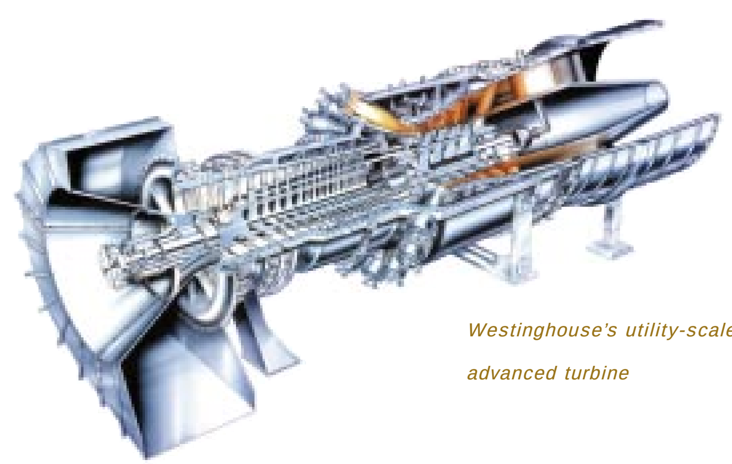
Other ATS program developments transferred to the 501G design are new thermal barrier coatings that permit higher turbine blade temperature.

Technology base research and development

Critical technology barrier issues for ATS include development of advanced materials, low-emissions combustion, advanced turbine cooling, and advanced component design methods.



General Electric's utility-scale advanced turbine



Westinghouse's utility-scale advanced turbine

CONCEPTS

General Electric	Developing two systems: a 9H (50 Hz) system, and a 7H (60 Hz) system
Westinghouse	Developing and testing 501G air-cooled engine as the precursor to an ATS design

Materials development. Projects include (1) single-crystal complex-cored airfoil technology to attain higher turbine inlet temperatures and (2) dependable thermal barrier coatings to enable increased turbine inlet temperatures while maintaining airfoil substrate temperatures at levels that meet ATS life goals. Emphasis is being placed on cost-effective casting of single-crystal components.

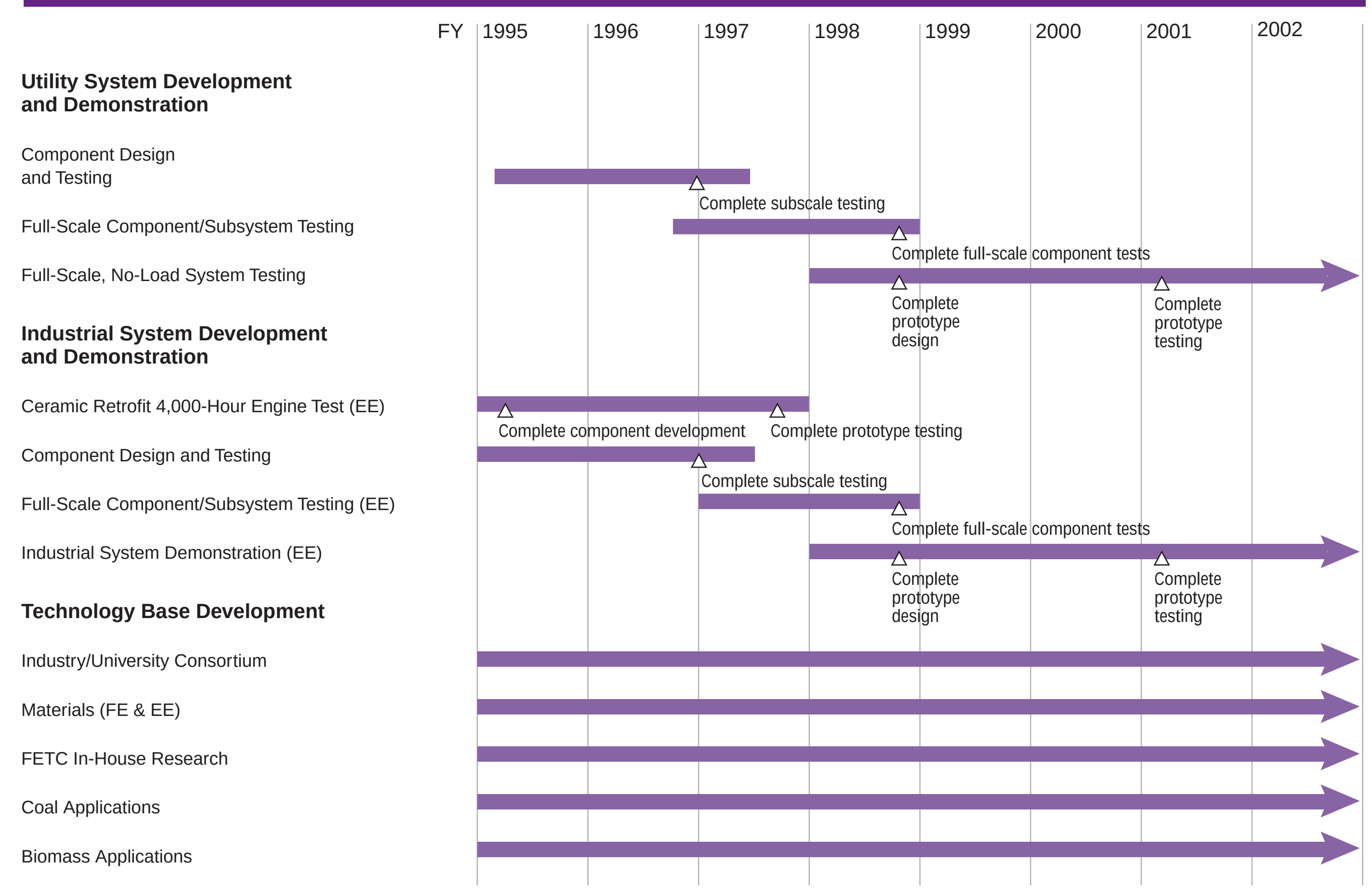
In-house R&D. FETC's combustion group, collaborating with university investigators, conducts laboratory tests to evaluate novel concepts for low-emissions-combustor modeling, mixing sensor development, heat-transfer sensor development, noise measurements in combustors, and combustor dynamics and control.

Industry/university consortium. DOE supports applied research for 95 U.S. universities, including workshops and student internships at industry facilities. Under the direction of the South Carolina Energy and Research Development Center, contracted universities perform applied research specific to the needs of major ATS developers in combustion, aerodynamics, materials, and heat transfer.

INDUSTRY/UNIVERSITY CONSORTIUM SUCCESSES

University of California at Berkeley	Probe for in-situ measurements of fuel/air ratio
Syracuse University	Computer code to optimize turbine design
Georgia Institute of Technology	Process for producing thermal barrier coatings Control strategy for eliminating combustion instability

ROADMAP FOR ATS PROGRAM



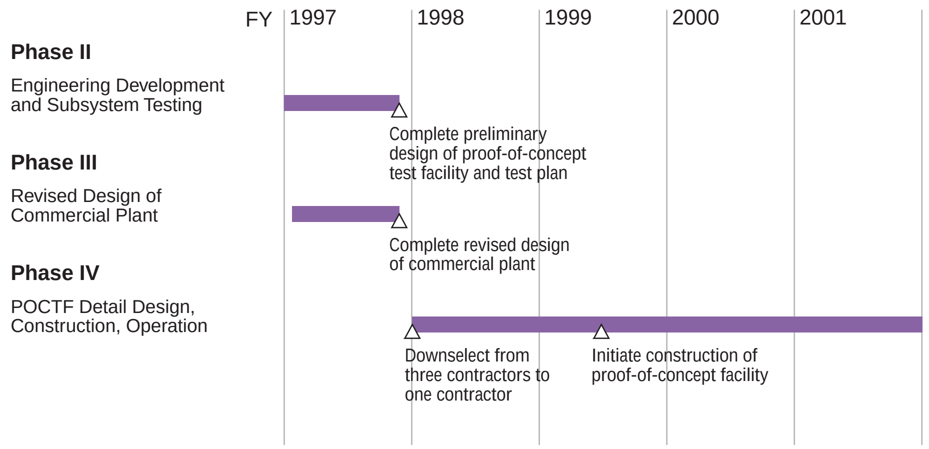
EE: Office of Energy Efficiency and Renewable Energy
FE: Office of Fossil Energy

To date, the consortium has conducted 51 projects that include combustion to improve fuel utilization and minimize environmental effects, heat transfer and aerodynamics to upgrade turbine blade life and performance, and materials to extend life and withstand higher operating temperatures for more efficient systems.

Humid air turbine (HAT) combustion testing. FETC and its industrial partner, United Technology Research Center, are identifying combustor configurations to efficiently burn high-moisture, high-pressure gas/air mixtures, resulting in low emissions for systems where injected moisture can boost both power and efficiency.

Computer models are being developed to aid in the design of combustion systems that operate with humidified air. In-house testing of new combustor components is under way. Test data will be compared to computer models for design of full-scale engine combustors.

ROADMAP FOR LEBS PROGRAM

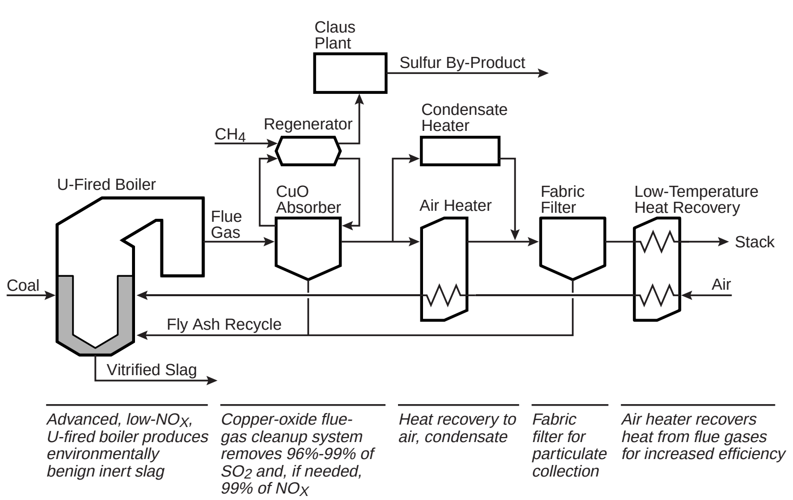


LOW-EMISSIONS BOILER SYSTEM

The low-emissions boiler system (LEBS) is a highly advanced pulverized-coal-fired powerplant being developed under an industry-DOE/Fossil Energy partnership. Its innovative design integrates components to maximize benefits achieved from advances in low-NO_X combustion, flue gas cleanup, and power-cycle technology at the lowest possible cost.

LEBS can be adapted to specific user requirements, such as limits on fuel availability, local regulations, and site conditions. It is positioned for ready acceptance by the electric power industry at home and overseas.

LOW-EMISSIONS BOILER SYSTEM



LEBS performance offers dramatic improvements over conventional coal-fired powerplants. Higher thermal efficiency will cut CO_2 emissions by 15% to 20% over today's new plants. Emissions of acid gases (SO_2 and NO_X) will be one-sixth or lower and particulate matter emissions one-third of current NSPS limits. Significantly, this is to be achieved along with a reduction in the cost of electricity.

After nearly five years of systems analysis, engineering development, and testing, three cost-shared industry teams delivered 400-MW commercial plant designs and proposed proof-of-concept approaches. In September 1997, the team led by DB Riley was chosen to construct an 80-MW LEBS plant at Elkhart, Illinois, adjacent to the Turris Coal Company mine, which produces Illinois #5 high-sulfur coal. The plant will use a low-NO_X, U-fired furnace developed under the LEBS program. A 10-MW test module for the moving-bed copper-oxide flue-gas cleanup process will also be built and operated.

Nearly all coal ash is converted by the U-fired furnace into a glass-like slag by-product that can be used in the construction industry. The volume of slag is only one-third that of the fly ash produced in a conventional coal boiler, significantly reducing solid-waste-handling requirements.

LEBS PERFORMANCE

Efficiency	42% to 45%
NO_X emissions	0.1 lb/10^6 Btu
SO_2 emissions	0.1 lb/10^6 Btu
Particulate emissions	0.01 lb/10^6 Btu

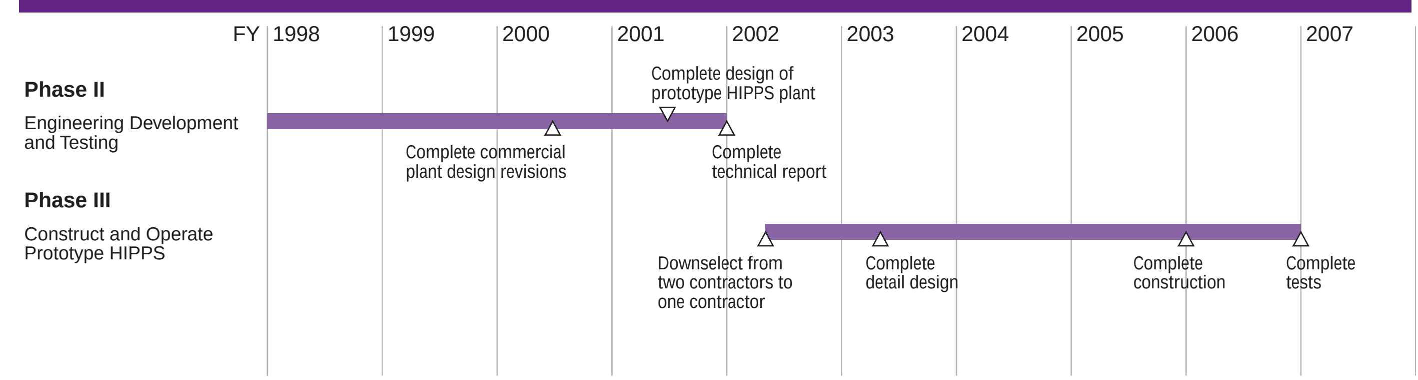
The furnace will use staged combustion and a concept called "reburning" to reduce NO_X pollutants. Flue gas leaving the boiler can be further cleaned of NO_X and SO_2 in the copper-oxide process. Ammonium sulfate fertilizer will be produced from the by-product streams.

HIGH-PERFORMANCE POWER SYSTEMS

The key to developing an indirectly fired cycle is learning how to transfer heat from combustion to the turbine air in a high-temperature air furnace (HITAF). This requires both innovative engineering and advanced materials. To realize high system efficiency, the HITAF must operate at higher temperatures than conventional coal-fired steam boilers.

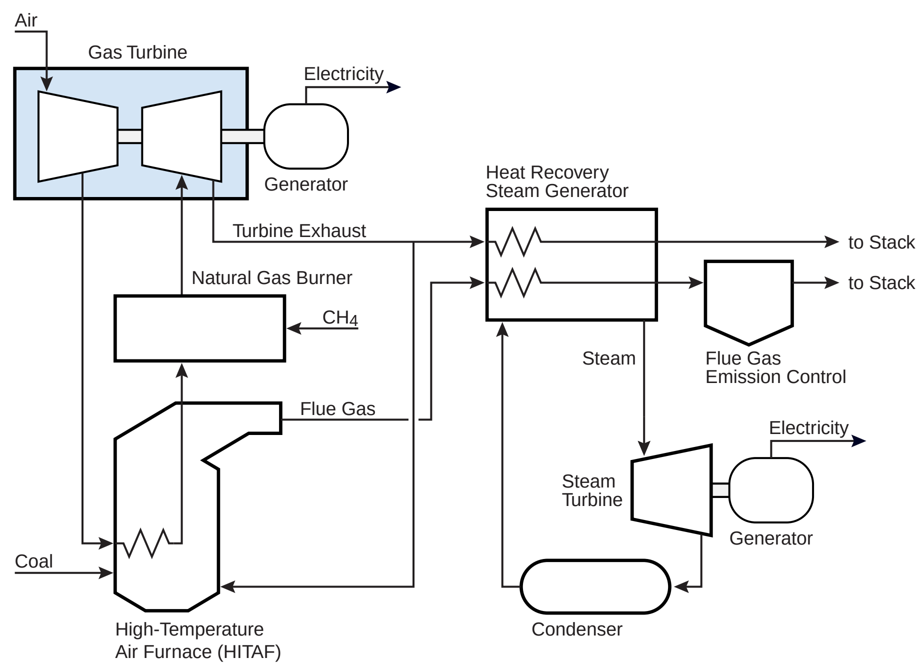
Two industry teams, led by Foster Wheeler Development Corporation and United Technologies Research Center, have been developing different versions of HIPPS. When fully developed, both versions are to be capable of achieving efficiencies of 55%. Less advanced configurations of HIPPS technology, available now, can be used to repower existing coal-fired plants to increase both their power output and efficiency.

ROADMAP FOR HIPPS PROGRAM



HIGH-PERFORMANCE POWER SYSTEM

In the HIPPS indirectly fired cycle, air is heated in a coal-fired, high-temperature air furnace (HITAF) to a temperature approaching the gas turbine inlet temperature. Natural gas or a clean-coal-derived fuel can be used to reach inlet temperature. This hot air is expanded in the turbine, producing over half the system's power output. Heat recovered from turbine exhaust and from the HITAF flue gas is used to raise steam for the steam turbine, to create more power. HIPPS will achieve an efficiency of 55% and has drawn potential as a key combustion-based technology module for Vision 21.



FLUIDIZED-BED COMBUSTION

Advanced fluidized-bed combustion (FBC) technology offers a viable power generation option for the post-2000 time frame. Commercial FBC units operate at competitive efficiencies, cost less than today's units, and have NO_X and SO_2 emissions below levels mandated by Federal standards.

FBC comprises three technology variations: atmospheric FBC, first-generation pressurized FBC or PFBC, and second-generation PFBC. Second-generation PFBC systems include a carbonizer reactor and topping combustor to increase efficiency levels.

Researchers in seven FBC subprograms are demonstrating advanced features of FBC and providing R&D to lower capital and production costs. Thrusts include simplification of FBC systems and components, incorporation of alternative feed and withdrawal systems, and incorporation of advanced subsystems and steam cycles.

Results from system studies will guide future R&D. Optimum turbine-compressor configuration and operation of first-generation PFBC are being studied. Optimum configurations of second-generation PFBC for Vision 21 concept plants with fuel cells and CO_2 sequestration options will be developed. Gas turbine studies will be performed on gas compositions and heat capacities specific to PFBC, which can lead to higher allowable turbine blade temperatures.

Advanced FBC systems demonstration

Two CCT projects are providing valuable information: one at Lakeland, Florida, demonstrating commercial-scale advanced pressurized FBC technology by 2002; and the other at Jacksonville, Florida, demonstrating circulating atmospheric FBC by 2000.

Topping combustor/turbine

Developing and demonstrating a topping combustor with suitable fuel flexibility, flame stability, and NO_X-emissions characteristics is critical to commercializing second-generation PFBC systems. Tests of a multi-annular swirl burner (MASB) have demonstrated good flame stability and NO_X performance. Systems testing of the MASB was performed at the Wilsonville Power Systems Development Facility (PSDF) during 1998, and integration of the MASB into ATS designs will occur after the turn of the century.

Combustion by-products utilization

FBC economics improve as combustion by-products are reduced or high-value uses are found. The goal is to reduce solid by-products from FBC systems without compromising sulfur capture or producing in-bed sintering. Variability of limestone will be assessed as a factor in the volume of solid by-products, and a limestone utilization model will be developed to optimize sulfur capture and minimize the volume of solid by-products.

Net operating costs and landfill requirements will be reduced by expanding markets for FBC by-products. FBC ash will be characterized for conventional applications, such as agriculture, mine remediation, and structural fill, and high-value uses of solid by-products from FBC systems will be developed.

Hot-gas filtration

Filter element durability, filter-ash bridging, and system costs are critical development issues being addressed. The challenge of producing candle-filter elements able to operate for more than three years is being met by enhancing monolithic filter elements made of various materials, such as clay-bonded silicon-carbide, porous-sintered metal, and alumina-mullite oxide.

A number of composite-type ceramic and iron aluminide-type filter elements are also undergoing development.

Filter cost can be reduced by 25% through optimized design of the system; filter vessel cost is about 75% of the total system cost.

Solids transfer

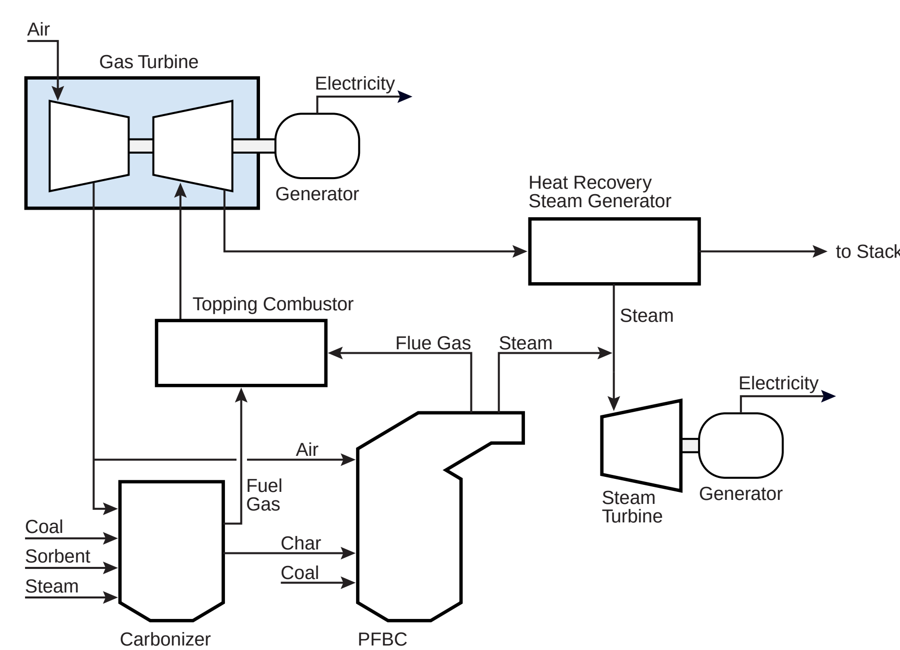
Cost reduction and reliability improvement can be achieved by improved handling of hot-solids material—feed and withdrawal, flow control, and fines removal. A feasibility study of a rotary high-pressure dry-solids feeder will evaluate the system's potential for reducing capital and operating costs.

An advanced system for simpler and more reliable transfer of hot char from the carbonizer to the fluid-bed combustor will be tested for its ability to decrease materials flow and handling-related downtime by at least 50%.

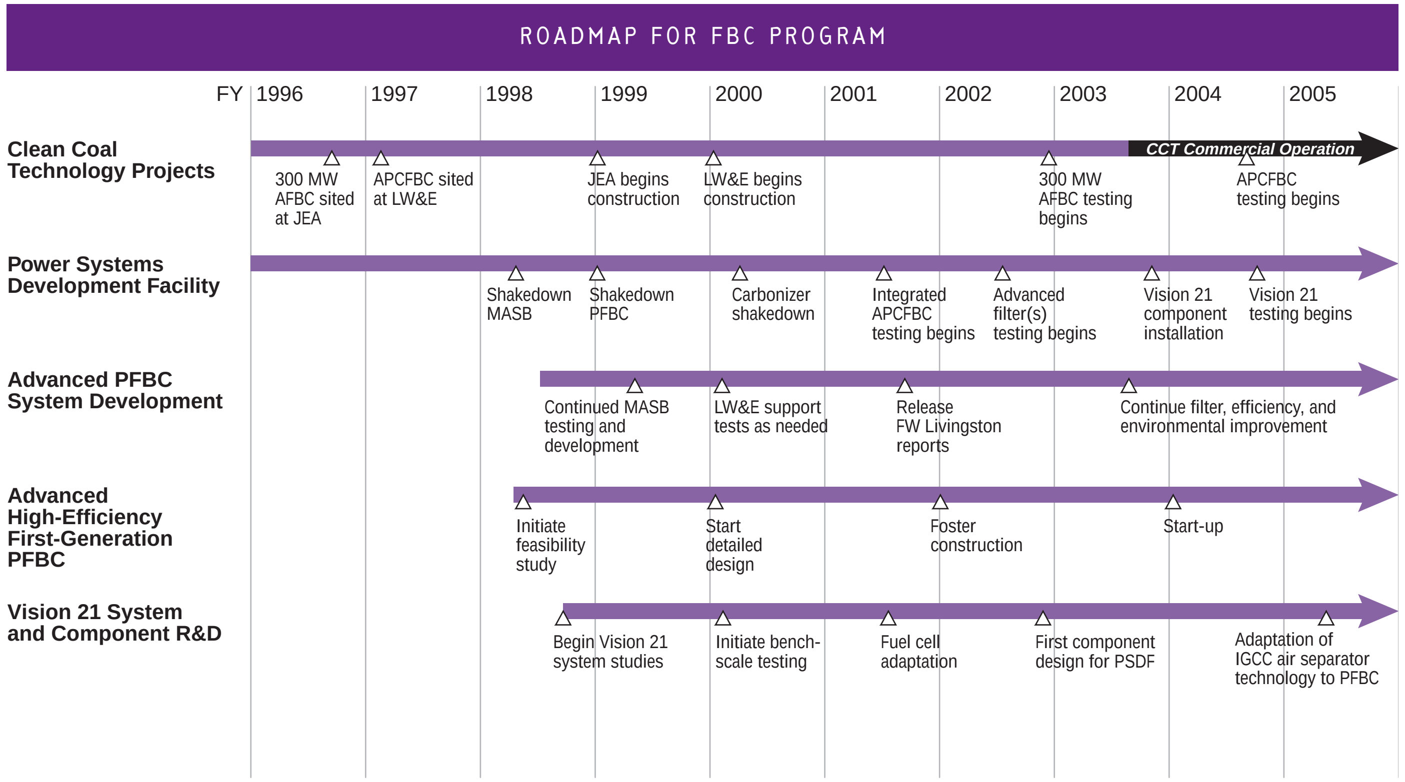
Sulfur/alkali removal

Alkali in hot-gas streams can limit gas turbine life and reliability. The severity of the alkali problem must be determined. Gas turbine tolerance to alkali, the amount of alkali released, the effect of filter-cake characteristics, and the ability to control alkali will be assessed. Also, experiments to determine sulfur removal and trace-contaminant levels in the gas stream during integrated demonstration will be conducted.

SECOND-GENERATION PFBC SYSTEM

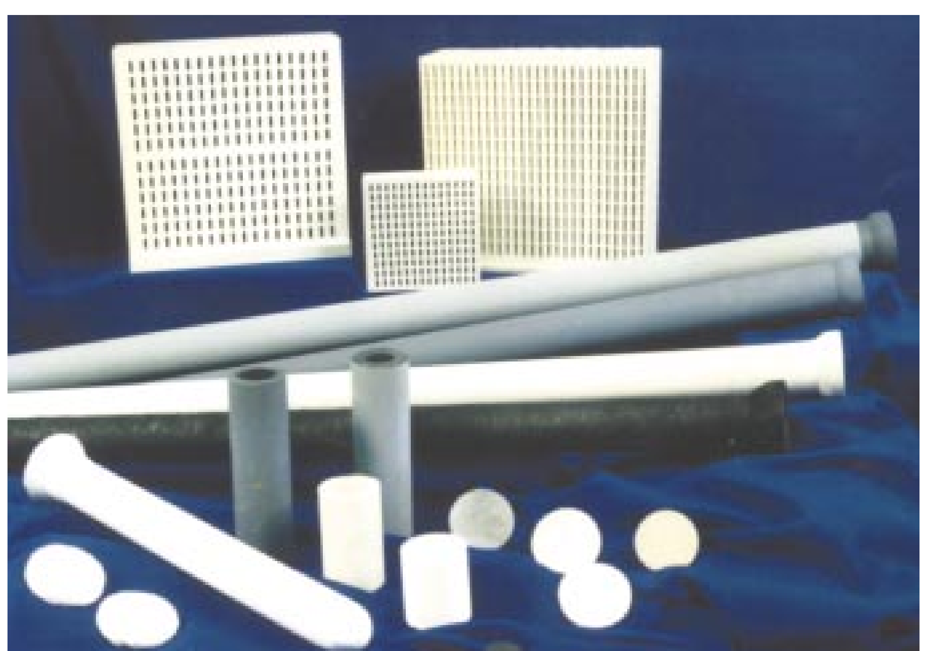


In a second-generation PFBC system, the feed is partially gasified in a pressurized fluidized-bed carbonizer. The carbonizer produces a low-Btu gas and a char. The char is burned in a PFBC. Both gases are cleaned by hot-gas filtration, and the pyrolyzer gas is burned in a topping combustor to heat the PFBC flue gas. The hot gas drives a gas turbine to generate power. The flue gas generates steam in a heat recovery steam generator, which is used to generate additional power. At the Wilsonville Power Systems Development Facility (PSDF), a highly advanced second-generation PFBC now demonstrates high efficiency at pilot scale.



Cofiring of biomass and industrial by-products

Existing fluidized beds are suitable for cofiring, but, to date, only 8 of the 100 units in the U.S. cofire material. Cofiring of biomass and industrial by-products could evolve into a standard practice as a near-term means to reduce CO_2 emissions. R&D data on heavy metals are needed so that environmental approval and permits for cofiring projects are not any more difficult to obtain than for single-fuel solid-combustion units.



Filter element durability, as it translates into useful performance life, is a critical factor for reducing FBC operating costs. Long-term studies of various types of hot-gas filters are being performed to study durability and performance.

IGCC MARKETS

- Domestic and international baseload power
- Domestic repowering
- Refinery cogeneration
- Pulp and paper
- Steel and aluminum
- Coproduction of fuels and chemicals

INTEGRATED GASIFICATION COMBINED-CYCLE SYSTEMS

The integrated gasification combined-cycle (IGCC) process provides industry with low-cost, highly efficient options for meeting a wide spectrum of market applications.

IGCC is one of the most efficient and environmentally friendly of today's commercial and advanced coal technologies. Gasification technology can process all carbonaceous feedstocks, including coal, petroleum coke, residual oil, biomass, and municipal and hazardous wastes, and is the only advanced power-generation technology capable of coproducing a wide variety of commodity and premium products to meet future market requirements.

IGCC technology is applicable to both domestic and international baseload and repowering applications. Industrial markets also include the production of environmentally superior transportation fuels, premium chemicals, and commodity products. IGCC systems are also very effective in converting hazardous industrial wastes into valuable, benign products.

Coal gasification processes must compete economically with natural-gas combined cycle technologies. Therefore, capital cost must be reduced, and reliability and capacity utilization must be improved. The use of natural-gas combined cycle today could be beneficial for IGCC tomorrow, because as natural gas prices rise, gasification units can be readily installed to replace natural gas.

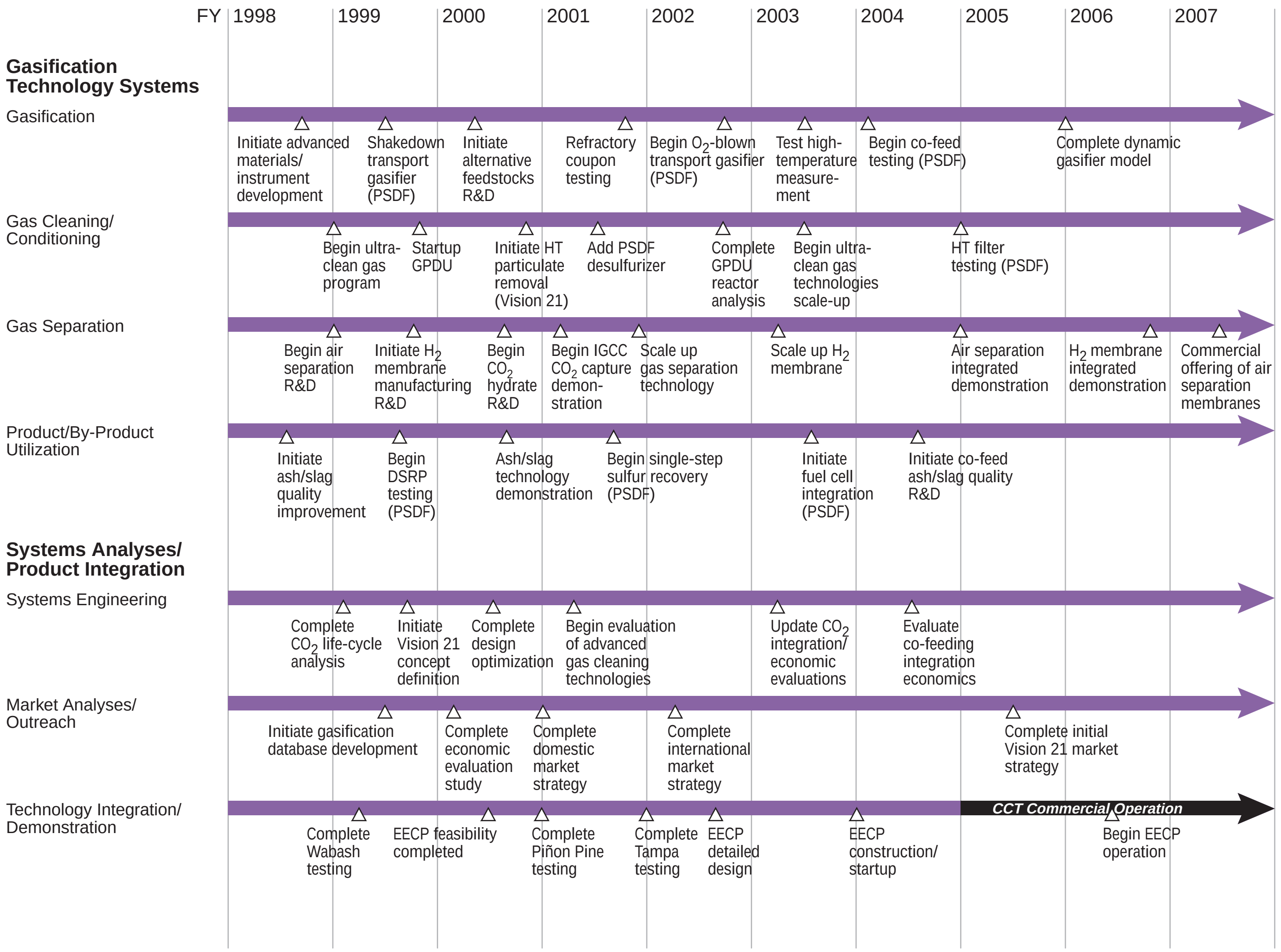
Gasification systems technology

The IGCC program strategy emphasizes capital and operating and maintenance (O&M) cost reductions, increased efficiencies, feedstock and product flexibility, and near-zero emissions of pollutants and carbon dioxide to meet future energy market demands and break the barriers to global commercial acceptance of gasification-based technologies. To achieve these goals, the strategy focuses on research and development of gasification system technologies, the conduct of engineering analyses, and the integration of advanced technologies from other programs, where appropriate.

Gasification. Advanced gasification technologies, such as the transport gasifier, are being developed through a coordinated program. Researchers are also developing fluid dynamic data and advanced computational fluid dynamic models to support the development of these advanced gasifiers. Investigations are being conducted to develop improved refractory materials and advanced instrumentation to enhance gasifier performance, reliability, and control.

The Power Systems Development Facility provides a critical bridge between research- and commercial-scale demonstrations of IGCC technology.

ROADMAP FOR IGCC PROGRAM



Alternative feedstocks such as petroleum coke, biomass, and municipal waste in conjunction with coal are being evaluated as feedstocks for power and coproduction applications in existing and advanced gasifiers.

Gas cleaning/conditioning. Research in this area is intended not only to reduce capital and O&M costs and increase the efficiency of IGCC systems, but also to meet more stringent gas quality requirements for cogeneration and coproduction applications. These new technologies are needed to ensure the supply of ultra-clean gas for fuel cell integration, to enable the catalytic conversion of synthesis gas to fuels and chemicals, and to enable advanced processes to effectively separate carbon dioxide. Advanced sorbents are being explored and novel technologies are being developed to achieve near-zero emissions of particulates, sulfur and nitrogen oxides, and hazardous air pollutants, and to minimize consumables and waste products. A wide range of process conditions are being considered in order to meet specific downstream processing requirements.

Gas separation. Advanced gas separation technologies are being developed that have potential for reducing capital and operating costs, improving plant efficiency, and concentrating and capturing carbon dioxide. New air separation technologies that use mixed-conducting ceramic membranes and that have potential for significant cost reductions and efficiency improvements are being developed.

Researchers are also investigating novel hydrogen separation technologies that are capable of operating at high temperatures and pressures for use in conjunction with fuel cells to improve overall IGCC plant efficiency. Tolerance to chemical and particulate contaminants, the ability to conduct reactions of carbon monoxide with water (the water-gas shift reaction) for the production of additional hydrogen, and the ability to concentrate CO_2 are critical issues that must be addressed to meet the goals of Vision 21. Other novel concepts for concentrating CO_2 from various IGCC process streams are being investigated.

Product/by-product utilization. This area focuses on developing technologies that can improve the utilization of process and waste streams to generate value-added marketable products and to minimize waste disposal costs. Technologies that improve the quality and marketability of gasifier slag and ash are being developed to enhance IGCC plant revenues and minimize waste disposal costs. These technologies will be particularly important when co-feeding coal with alternative feedstocks such as municipal waste and biomass. Processes are also being developed for the direct production of elemental sulfur from the waste streams produced by the gas cleanup technologies. In addition, work will also focus on the integration of fuel cell and fuel cell/turbine hybrid systems.

Systems analysis/product integration

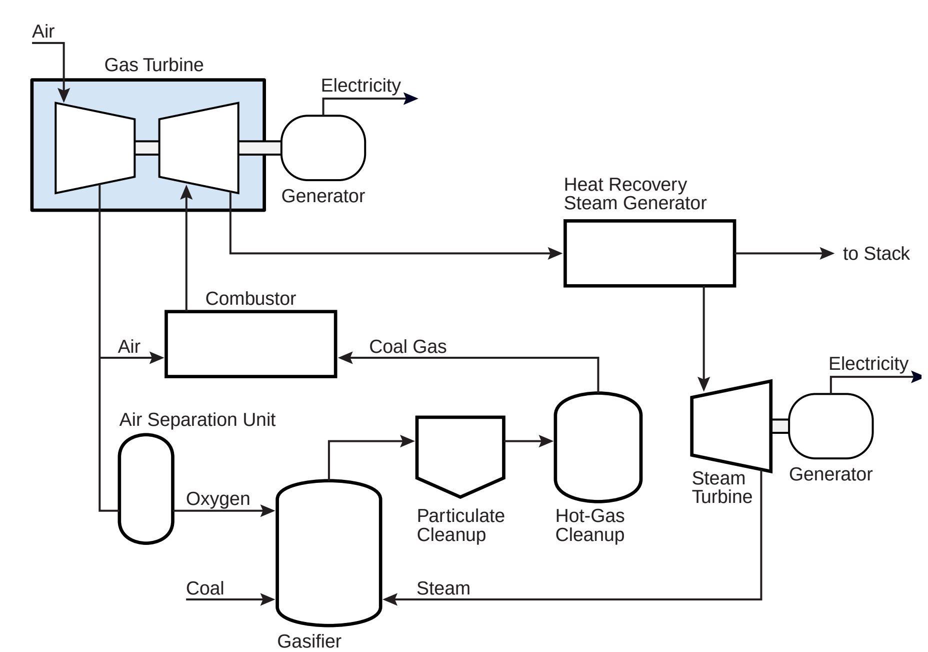
Economic analyses, process performance assessments, and market studies are planned to provide sound engineering and economic guidance for future R&D initiatives and to support commercialization activities, both domestically and internationally.

Systems engineering. An IGCC optimization study is being performed for baseload power applications, the cogeneration of power, steam, and hydrogen, and the coproduction of power, fuels, and chemicals. Through the use of advanced engineering design concepts for heat integration, equipment sizing, and construction, and the use of market-based costs, this study will provide the lowest-cost, highest-efficiency IGCC systems. This study, together with other engineering analyses, will be used to identify future R&D efforts to further reduce material cost, consumables, and total plant cost. In addition, these studies will be used to increase plant efficiency and profitability and to reduce emissions through integration of advanced gasification system, power generation, and synthesis gas conversion technologies.

The IGCC program, together with the Fuels program, is embarking on a cost-shared feasibility study of an advanced coproduction plant, called the Early Entrance Coproduction Plant (EECP).

INTEGRATED GASIFICATION COMBINED-CYCLE SYSTEM

IGCC systems are ideally suited to deliver a suite of energy products to meet future market requirements. IGCC systems use a gasifier to convert carbon-based feedstocks into synthesis gas (a mixture of carbon monoxide and hydrogen). The gases are cleaned of particulates, sulfur, and other contaminants before being combusted in a high-efficiency combined-cycle gas and steam turbine system to produce electricity, or are catalytically converted to high-value transportation fuels or chemicals. In addition, hydrogen and steam can be produced.



DEMONSTRATED SUCCESS FOR IGCC

Through cost-shared efforts by the Department of Energy and industry partners, the promise of gasification has been demonstrated in three coal-based IGCC plants that now provide reliable commercial service and a proving ground for IGCC technology.

A unique combination of gasification, gas cleanup, and advanced turbine technologies, IGCC systems offer an attractive approach for providing clean, affordable electricity as well as other valuable products. IGCC plants operated by the Sierra Pacific Power Company, Tampa Electric Company, and PSI Energy, Inc., now serve electricity customers with low-cost, environmentally friendly power. In the future, as a key integral unit in Vision 21 plants, IGCC units like these will supply synthesis gas, steam, transportation fuels, chemicals, and hydrogen, in addition to power.

By converting carbonaceous feedstocks such as coal and biomass to high-value and commodity products as well as to baseload power, IGCC can meet diverse national and international energy market needs. Coproduction of energy products maximizes returns on investment in these facilities while minimizing waste and environmental impact.

Thanks to investments in energy R&D by the Federal government and industry partners, U.S.-based companies are well-positioned to apply IGCC systems at home and to capture a healthy share of what promises to be a multi-billion-dollar export market for clean power-generation technologies.

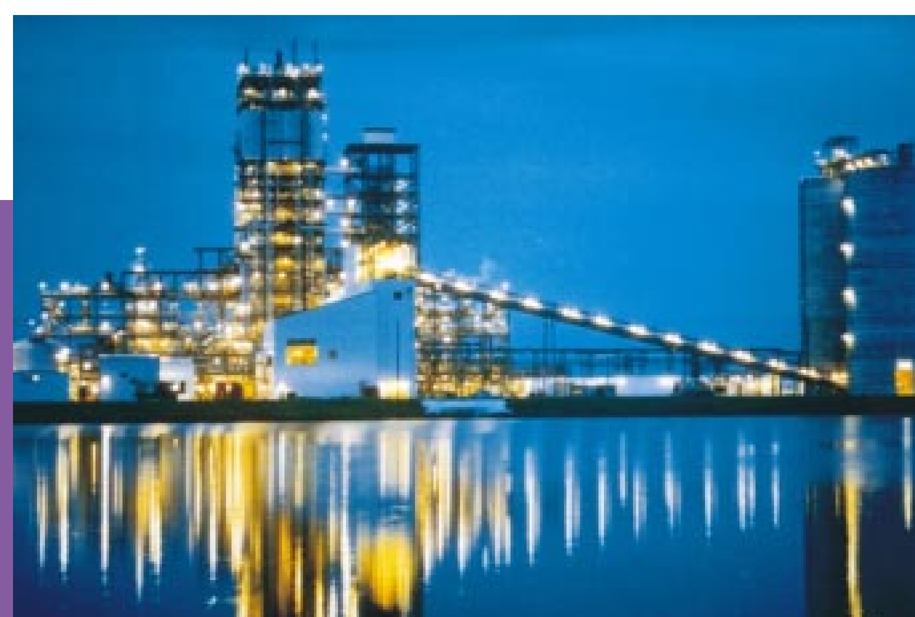
It is intended that the results of this program and supporting R&D will lead to the construction and operation of a first-of-a-kind Vision 21 plant.

Market analysis/outreach. A detailed analysis of the market potential of IGCC technologies in conventional and niche market applications, both domestically and internationally, is being conducted. Using the results of this study, a commercialization strategy will be formulated for use in the next decade. This, together with a technology database currently undergoing development, will provide important information to both the public and private sectors for future decision making.

Technology integration/demonstration. Two key components of the IGCC program are the Power Systems Development Facility (PSDF) in Wilsonville, Alabama, and the Gas Processing Development Unit (GPDU) in Morgantown, West Virginia. These two facilities provide the critical link between R&D and commercial-scale demonstrations. Through cost-sharing industrial partnerships, these facilities will provide the means for performing integrated system and component testing at a scale of operation relevant to industry.

The four CCT IGCC demonstration projects, Tampa Electric, Wabash River, Piñon Pine, and Clean Energy, are also key elements of the IGCC program. These projects are currently confirming process scale-up, evaluating process performance, and providing data on reliability, availability, and maintenance. DOE will maintain an active role in these projects by providing technical assistance and supporting R&D to enhance their success.

The Tampa Electric IGCC system, built as a greenfield site, is one of the cleanest and most efficient coal-fired powerplants in the world.



FUELS

Coal and natural gas are versatile fuels and feedstocks. Improved solid fuels and economically competitive transportation fuels from gas and coal are expected near-term products of DOE programs. A key emphasis in transportation-fuels development is the production of high-quality, clean-burning diesel fuels from both natural gas and coal. The solid fuels and feedstocks program examines the environmental and economic benefits of blending biomass and waste feedstocks with coal, develops tailored feedstocks for making premium carbon products, and provides the means to remove trace contaminants from coal.

Through Vision 21, advanced technologies for coproducing power and fuels will enable our Nation to use its plentiful fossil resources to fulfill a broader range of energy and chemical feedstock needs while reducing impacts to the environment.

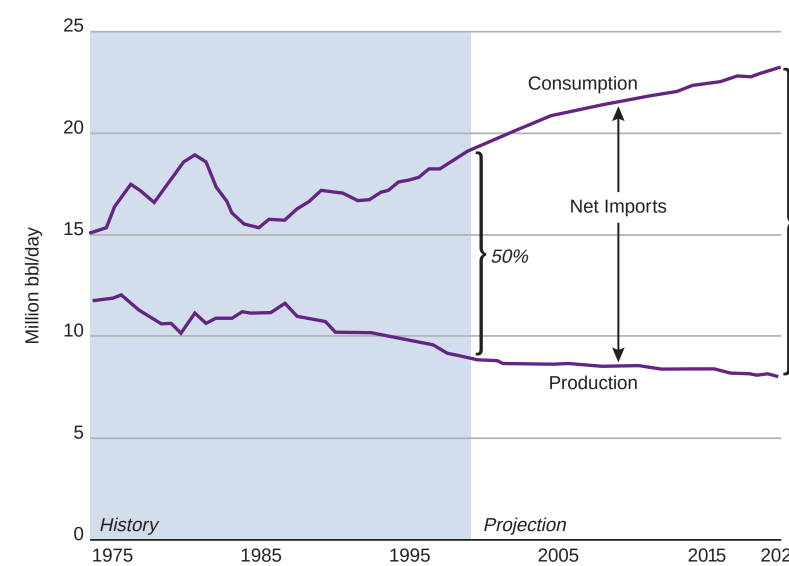
TRANSPORTATION FUELS

The Energy Information Administration (EIA) predicts that, by 2020, U.S. petroleum imports, already representing over 50% of consumption, will rise to 65% and increase our negative balance of payments. Total worldwide oil demand will double, creating a very competitive market for imports from sources that are likely to be politically unstable. From an environmental perspective, vehicles currently account for a large portion of urban air pollution, including carbon monoxide, nitrogen oxides, volatile organic compounds, and particulates. The transportation sector also contributes about one-third of U.S. greenhouse gas emissions. Further limits on emissions are likely and will be difficult to meet with conventional fuels.

The coal liquefaction technology program response to these environmental, energy security, and economic challenges is to provide the technical basis for a clean fuels industry capable of producing transportation fuels and chemicals from coal and other carbonaceous, non-petroleum domestic resources. Specifically, research is focused on developing clean fuels that (1) are environmentally superior to those derived from conventional petroleum-based fuels; (2) can satisfy the liquid fuel requirements of our Nation's transportation infrastructure; and (3) will help engine and vehicle manufacturers achieve higher performance with significantly lower emissions in both conventional and advanced systems.

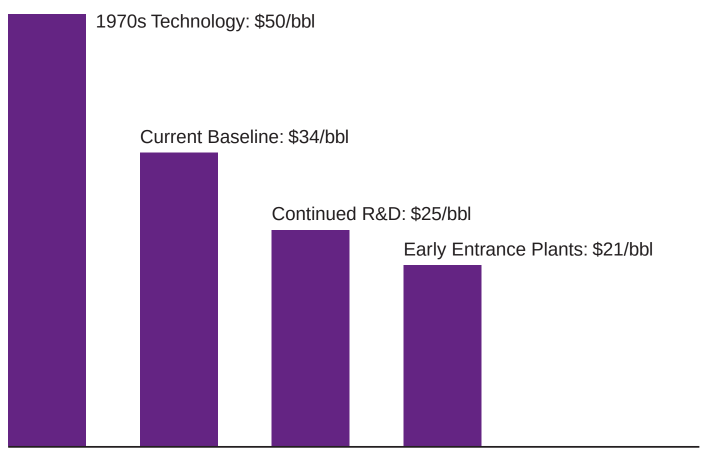
Many years of public investment in coal liquefaction and power systems RD&D have resulted in major advances, including reduced costs and mitigation of environmental impacts. Continued investments can provide the U.S. with technology options critical to our future energy security and economic strength.

EIA–PROJECTED U.S. CRUDE OIL PRODUCTION AND CONSUMPTION



Coal-derived transportation fuels can be an important element in the overall strategy to decrease our Nation's reliance on foreign oil. Currently, the United States uses 18 million barrels per day (bbl/day) of crude, over 50% of which is imported. Rising oil imports will worsen the balance of trade. Last year, the U.S. paid over $60 billion for imported oil; this amount could more than double (in constant dollars) by 2020.

COAL-DERIVED FUEL COSTS



Preliminary economic analyses indicate that liquid fuels can be coproduced at a cost equivalent to crude oil at $21 per barrel. These low costs can be achieved because of savings associated with integrating Early Entrance Coproduction Plants with existing petroleum refining facilities and using coal combined with low-cost feedstocks, such as petroleum coke and wastes.

Coal-derived liquid transportation fuels could also provide significant environmental benefits. Diesel fuels such as Fischer-Tropsch and high-cetane liquid oxygenates would enable the design of modified engines with improved efficiencies and up to 50% lower total emissions than conventional fuels.

To meet these research objectives and establish the foundation for a U.S. coal conversion industry by 2010, the program has developed strong partnerships with industry, academia, National Laboratories, and other government organizations to reduce the technical and environmental risks associated with commercial deployment. An example is the Early Entrance Coproduction Plant initiative, part of Vision 21, that is scheduled for implementation in FY 1999 as a joint effort with the IGCC program. Preliminary studies show that integrating technologies such as coal-based power and fuel production at one facility can offer economic and environmental benefits when compared with stand-alone plants. Teams will be pursuing industry-government cost-shared research and engineering studies that will be directed toward privately funded design, construction, and operation by 2007 of a first-of-a-kind commercial facility that coproduces multiple products—some combination of power, fuels, and chemicals.

Technologies are being developed in a time frame consistent with FE's mid-term Early Entrance Coproduction Plant strategy. Through cost-shared partnerships, program resources will be leveraged to provide the Nation with the capability to produce significant quantities of coal-derived transportation fuels, chemicals, and carbon products after 2010.

Technology status and direction

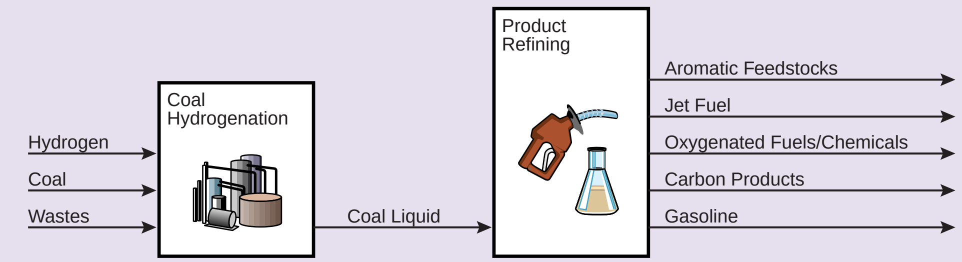
With current technology, the cost of producing direct liquids in stand-alone plants would be about $30 per barrel. The cost can be reduced to the $21-per-barrel target by coprocessing coal with low-cost feedstocks. Research has shown that these liquids can then be upgraded, at lower cost than crude oil, using conventional petroleum refining technologies to produce high-octane gasoline, jet fuels, and valuable chemicals. These fuels have much lower levels of pollutant-producing sulfur and nitrogen than those of typical petroleum crude.

R&D will pursue process improvements in the direct hydrogenation of coal—alone and in combination with petroleum residuals and waste material—including the development of more efficient reactors, more active and robust slurry catalysts, and methods that produce hydrogen more economically and reduce its consumption during liquefaction. Multiple feeds will be studied to reduce the production of greenhouse gases. Early commercial entry of direct liquefaction technology would most likely involve coprocessing heavy residual oil at a refinery.

Novel three-phase slurry reactor technology is also being developed to cost-effectively produce premium fuels, an excellent diesel-fuel blending component, or high-value chemicals using syngas produced from natural gas or coal.

DIRECT LIQUEFACTION

In a direct route from coal to transportation liquids, coal's large, complex structure is broken down and converted into distillate crude. During this process, hydrogen is added to the coal, raising the hydrogen-to-carbon ratio to a level comparable with that of petroleum crude.



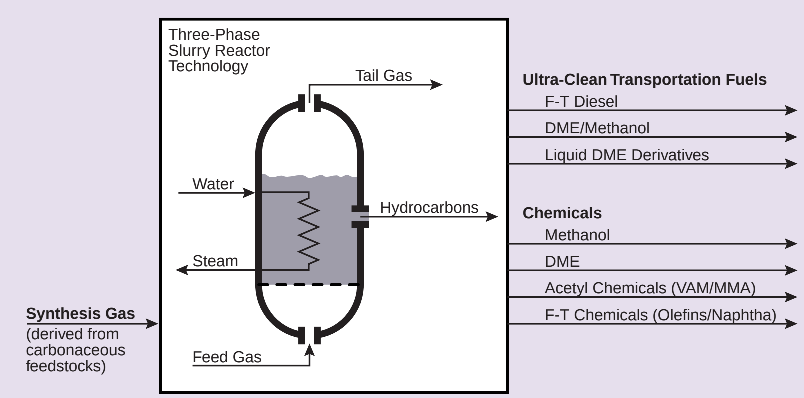
Because of its interest in the production of high-quality diesel fuel through the Fischer-Tropsch indirect liquefaction process, DOE's Office of Transportation Technologies is an important partner with the Office of Fossil Energy in developing fuels and transportation systems.

Early Entrance Coproduction Plant activities

To facilitate an industry-led effort to demonstrate advanced liquefaction technologies, the government will cost-share feasibility studies, R&D, and preliminary designs of first-of-a-kind commercial Early Entrance Coproduction Plants. These activities will help industry teams to refine their strategies, reduce technical risks, and define economic and environmental requirements. This information will enable the teams to pursue private-sector financing for detailed design, construction, and operation of their plants. One likely strategy would be to coproduce electricity, transportation fuels, and chemicals by integrating IGCC with indirect liquefaction. Feedstocks could include petroleum coke, wastes, and biomass in addition to coal.

ADVANCED SYNTHESIS GAS CONVERSION TO TRANSPORTATION FUELS AND CHEMICALS

Coal can also be converted to liquid form by an indirect route. Clean synthesis gas (hydrogen and carbon monoxide) is produced by gasifying coal with steam and oxygen. The synthesis gas is then reacted over catalysts to form premium refinery feedstock.



Systems engineering and analyses

Engineering and economic analyses are needed to define and prioritize future R&D initiatives and to support commercialization activities, both domestic and international. A major emphasis is on performing life-cycle environmental analyses on CO_2 emissions that arise from mining, transport, handling, conversion, and product utilization.

Proof-of-concept testing

Proof-of-concept (POC) evaluations to produce Fischer-Tropsch and other premium, high-performance fuels will provide optimum processing strategies and sufficient quantities of materials for engine and vehicle tests. All coal-fuels R&D, which culminates in POC activities and fuel testing, is focused, and will continue to focus, on developing fuels that assist the transportation sector in meeting its future emissions requirements. To this end, partnerships have been created with other Federal organizations and their stakeholders to facilitate commercial deployment of these advanced, alternative fuels.

Novel R&D in coal liquefaction

Computational chemistry techniques will be used to more efficiently develop kinetic models of coal conversion processes, which will in turn greatly reduce the laboratory R&D needed to effect process improvements. In addition, R&D will examine innovative hydrogen production technologies that have the potential to provide for both sequestration of CO_2 and significant reductions in manufacturing costs.

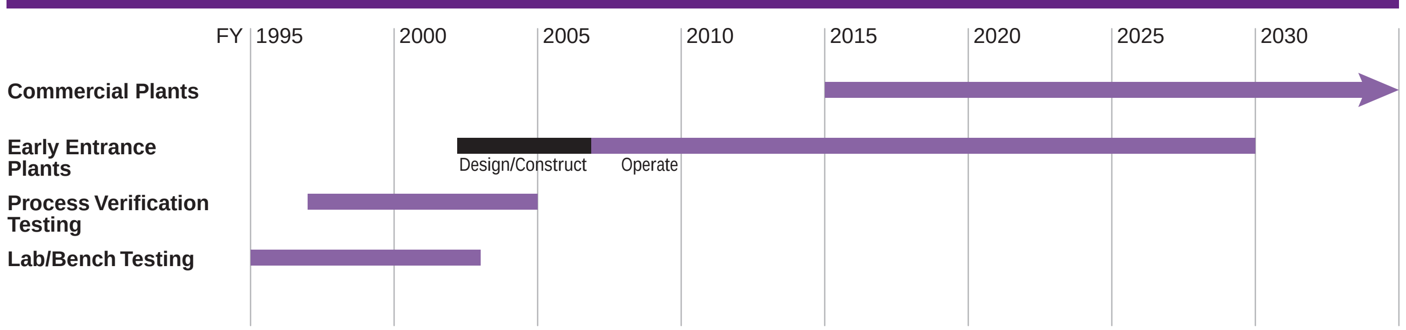
SOLID FUELS AND FEEDSTOCKS

The Solid Fuels and Feedstocks (SFF) Program is developing and commercializing advanced technologies for processing carbon-based solid materials that will (1) maintain U.S. industrial competitiveness, (2) contribute to efficient power production, and (3) promote environmental quality. A number of significant successes have already been achieved by the program. For example, the Microcel® flotation column developed with DOE support has had significant commercial success in coal and minerals applications, with over 50 units in use worldwide. Other successes include development of the Micro-Mag® heavy-medium cycloning process for coal cleaning and the GranuFlow® process for improved coal fines handling.

Based on the results of two successful workshops held to acquire stakeholder input, the Solid Fuels and Feedstocks Program is focused on activities to develop advanced technologies for the production of environmental solid fuels and tailored carbon feedstocks. The "Environmental Solid Fuels" activity is developing advanced technologies to enable the efficient use of coal, biomass, and waste fuels, while addressing existing and future environmental regulations and concerns associated with hazardous air pollutants, greenhouse gas emissions, and waste disposal / land reclamation issues. It includes the preparation and utilization of coal / biomass / waste composite fuels to permit a greater percentage of renewables to be utilized in new and existing power production systems to reduce CO_2 emissions by 10% or more. New approaches are also being developed to improve the recovery and handling of fine coal from existing production and waste coal ponds and piles.

The "Tailored Carbon Feedstocks" activity is concentrated on advanced technologies for the development of premium carbon products from coal and the preparation of specially designed (tailored) feedstocks for the production of advanced transportation fuels and chemicals from coal, biomass, and waste feeds.

ROADMAP TO COMMERCIAL DEPLOYMENT



Solid Fuels and Feedstocks Program key activities will result in new technology for: (1) precombustion control of potentially hazardous air pollutant emissions from coal by 2005; (2) converting one billion tons of impounded coal to clean fuel and the avoidance of the formation of new coal waste ponds by 2005; (3) facilitating 8 gigawatts of coal / biomass cofiring by 2010; and (4) producing cost-effective premium carbon materials from coal by 2015.

Environmental Solid Fuels

Research in this area is developing innovative methods for recovering useable fuels from materials that otherwise would be discarded at coal cleaning plants or utility power stations. Projects address the estimated 2 to 3 billion tons of coal fines that lie in waste impoundments at coal mines and washing plants around the country, the approximately 30 million tons of coal that is currently being wasted into ponds each year by active mining operations, and the millions of tons of unburned carbon found in powerplant fly ash landfills. Technologies are also being developed that combine coal and biomass or municipal solid waste into clean-burning fuels. A method for removing mercury from coal before it is burned, preventing the mercury from being released to form a hazardous air pollutant, is also being developed.

Other research in this area that will result in the more efficient use of solid fuels includes proof-of-concept (POC)-scale testing of a selective agglomeration process that uses a new mixing device (tubular processor); pilot-scale testing of an electrostatic separation process for dry, fine-size coal; and POC-scale testing of an advanced flotation control system. Industrial-scale testing of two advanced technologies will also be conducted—one for the production of carbonized slurry fuels for power production from coal, biomass, and waste and the other for the precombustion removal of contaminants from pulverized coal at utility powerplants. Work will also continue on the development of a national coal quality database on trace elements and cooperation with a broad-based, utility-sector consortium for coal utilization research.

Tailored Carbon Feedstocks

Premium carbon feedstocks and products are being developed by an industry-led, cost-shared consortium that will develop, demonstrate, and commercialize technologies for nonfuel uses of coal, such as:

- High-value premium carbon and graphite products
- High-strength, lightweight materials for improving fuel efficiency / reducing weight of vehicles
- Advanced feedstocks to reduce hazardous air pollutants, such as mercury
- Improved rechargeable batteries
- Fuel cell applications
- Chemically tailored carbon molecular sieves
- Adsorbents for water and air pollution control
- Specialty chemicals and coke
- Materials for heat-resistant applications

The Solid Fuels and Feedstocks Program uses engineering, market, and economic evaluations to understand how energy efficiency is improved and greenhouse and other gas emissions are reduced by new technology options for the production of metallurgical and foundry coke.

The Solid Fuels and Feedstocks Program investigates making premium carbon products from coal, such as high-quality graphite electrodes. (Courtesy of the Carbide/Graphite Group, Inc., Pittsburgh, PA.)