

THE U.S. DEPARTMENT OF ENERGY'S OFFICE OF FOSSIL ENERGY

# CLEAN GOAL TECHNOLOGY

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FROM RESEARCH TO REALITY



# CLEAN COAL TECHNOLOGY . . .

## FROM RESEARCH TO REALITY

ELECTRICITY IS THE INDISPENSABLE COMMODITY IN A MODERN ECONOMY. ALTHOUGH OFTEN TAKEN FOR GRANTED, A PLentiful AND CLEAN ELECTRICITY SUPPLY IS ESSENTIAL TO HOW AMERICANS LIVE, WORK, AND PLAY, FROM OPERATING COMPUTERS AND MACHINERY TO LIGHTING OUR HOMES AND POWERING THE ECONOMY.



More than 50 percent of the U.S. electricity supply comes from coal. Starting with the original Clean Coal Technology Program that began more than two decades ago, the U.S. Department of Energy (DOE) has engaged in innovative research and development (R&D) to transform research advances into market realities. Investment tax credits awarded under the Energy Policy Act are providing further momentum toward this goal.

With a clear vision and understanding of energy challenges in the new millennium, our Nation's leaders recognize the importance of finding new ways of extracting the power from coal — America's largest domestic energy resource — while simultaneously expanding environmental protection and confronting the issue of global climate change. Consequently, coal and coal technology are keystones of our national energy and environmental policies. The result: an unprecedented financial investment by both government and private industry in coal research, resulting in sustained, accelerated, and measurable movement of innovative technologies to the marketplace.

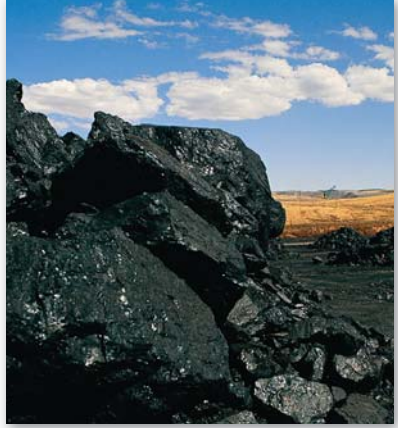
Everyone associated with DOE — scientists, researchers, administrators, and career employees — is proud of the role they've played in bringing about this remarkable achievement. Even more progress will unfold in the years ahead, such as the production of emissions-free electricity and hydrogen for emissions-free transportation. Combined with partners in industry, academia and other stakeholders, DOE has helped forge an enduring foundation for maintaining the integrity, flexibility and reliability of America's electricity supply — and a cleaner environment — throughout the 21st century. This is a legacy that will benefit millions of Americans, as well as people around the world, for generations to come.

“CLEAN COAL TECHNOLOGY” DESCRIBES A NEW GENERATION OF ENERGY PROCESSES THAT SHARPLY REDUCE AIR EMISSIONS AND OTHER POLLUTANTS FROM COAL-BURNING POWER PLANTS.

## PREPARING COAL FOR THE FUTURE

### WHY COAL?

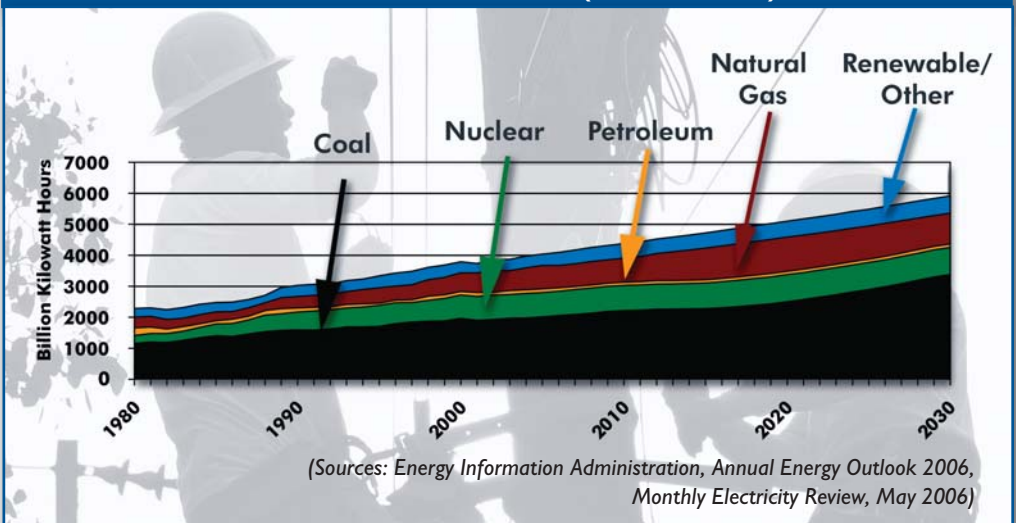
- We need it for our energy security.
- It is America’s largest domestic energy resource – enough to last 250 years at current rates of use.
- It is a versatile energy resource that can be used in solid, liquid, or gaseous form.
- It has traditionally been the largest single source of U.S. electricity generation, currently providing more than 50 percent of the total, and will continue to be the primary generator of America’s electric power for years to come.
- It can be used cleanly and affordably to drive our economic prosperity.



### HIGHLIGHTS — POLICY, PROGRAMS, PROGRESS

- Maximizing America’s ability to place more reliance on its massive coal resource means finding ways to eliminate pollution and to reduce the output of the greenhouse gas carbon dioxide, while still making energy affordable to all.
- Accelerating development of coal technology to achieve these objectives has been a cornerstone of the Bush Administration’s energy policies since 2000: It capitalizes on the success of the past and is ushering in a new era of energy and environmental security.
- The development and early deployment of advanced coal technologies are being supported through investment tax credits authorized under the Energy Policy Act of 2005.
- Commitment to clean coal technology has produced significant government and private sector cost-shared investments in clean coal research.

### U.S. ELECTRICITY GENERATION BY FUEL (1980–2030)



# CLEAN COAL TECHNOLOGY PROGRAM

## ...LAYING THE FOUNDATION

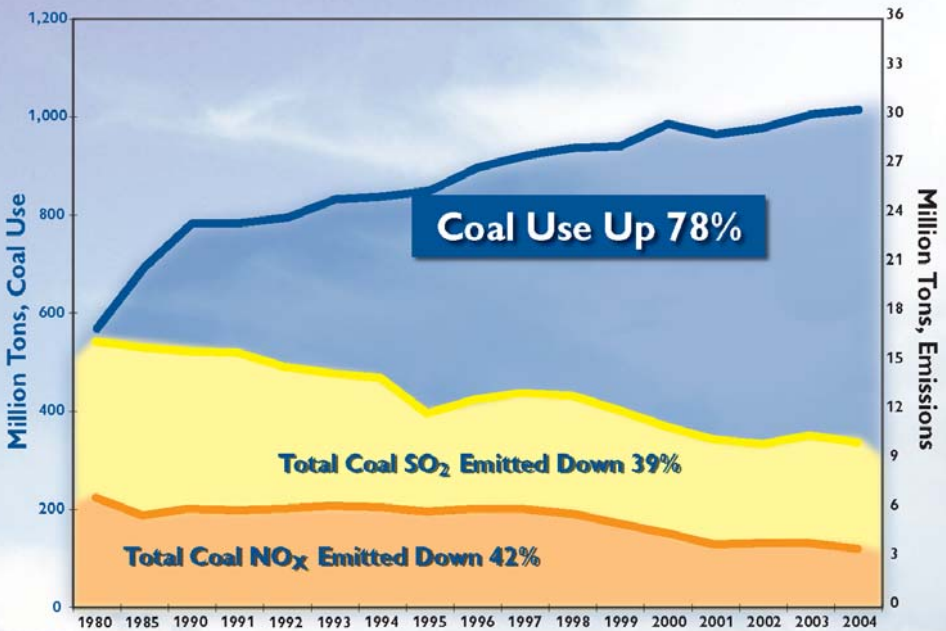


- Thirty-eight technology demonstration projects were selected and conducted between 1986–1993 – a jointly funded \$5.3 billion effort by government and industry; while the cost-sharing requirement was a 50/50 split, the private sector provided two-thirds of funds.
- The projects demonstrated and commercialized new lower-cost options for controlling emissions of sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>) at coal-based power plants, as well as improvements in plant performance and efficiencies.
- The results: 38 pioneering projects in 18 states that eventually produced 22 commercial successes (resulting in domestic or international sale of the technology, or the technology continuing to operate economically at the plant site).

## ...REAPING THE BENEFITS

TECHNOLOGY	IMPACT
LOW NITROGEN OXIDE BURNERS	Now on 75 percent of existing U.S. coal power plants . . . one-half to one-tenth the cost of older systems . . . 25 million ton reduction in U.S. NO <sub>x</sub> emissions through 2005, \$25 billion national benefit.
SELECTIVE CATALYTIC REDUCTION	Achieves NO <sub>x</sub> reductions of 80-to-90 percent or more . . . technology today costs half what it did in the 1980s, and is deployed on about 30 percent of U.S. coal plants.
FLUE GAS DESULFURIZATION (FGD)	Systems now cost one-third of what they did in the 1970s . . . more than 400 commercial units deployed . . . 7 million ton reduction in SO <sub>2</sub> (beyond what would have occurred without DOE R&D) through 2005, overall \$50 billion savings from the lower FGD costs and environmental improvement.
FLUIDIZED BED COMBUSTION (FBC)	170 units deployed in the U.S.; 400 units worldwide . . . highly commercialized, with more than \$6 billion in domestic sales and nearly \$3 billion in overseas sales . . . inherently low-NO <sub>x</sub> emitting technology capable of using coal waste fuels not previously usable, providing an economic/environmental benefit of \$2 billion through 2020.
INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)	In early stage, but 7.5 gigawatts (GW) projected ( <i>EIA's Annual Energy Outlook 2007</i> ) to be operating in U.S. by 2020 . . . estimated economic/environmental benefits of over \$12 billion by then.

## COAL USE UP, POLLUTION DOWN IN ELECTRICITY GENERATION



All data in million short tons. Figures are rounded. Total emissions reductions are due to several factors, which include increased commercialization and deployment of clean coal technologies.

(Sources: Energy Information Administration, Environmental Protection Agency)

## CLEAN COAL TECHNOLOGY = ADVANCED COAL POWER SYSTEMS

- Two “super clean” coal-based IGCC demonstration plants have operated reliably: Tampa Electric IGCC Power Plant in Mulberry, Fla., and PSI Energy Wabash River IGCC Power Plant in West Terre Haute, Ind.
- The JEA Northside Generating Station in Jacksonville, Fla., is one of the world’s largest circulating fluidized bed combustion power plants.
- Future demonstrations of carbon capture and storage technologies are planned at multiple commercial-scale integrated gasification combined-cycle (IGCC) coal power plants that will be operational by 2015

## HIGHLIGHTS — RESEARCH AND DEVELOPMENT

- Demonstrations of two mercury control technologies for existing plants aimed at 50–70 percent removal now and 90 percent removal in a few years.
- Lignite drying technology that can raise generating efficiency and lower pollution.
- Moving clean coal technology forward, including improvements to IGCC, bringing down the cost of CO<sub>2</sub> capture, finding better ways to store carbon dioxide, moving toward a hydrogen economy.
- By 2012, advanced turbines, capable of firing up to 100 percent hydrogen, will be integrated into power plants that separate and capture CO<sub>2</sub>.
- Continued concentration on lowering the costs of pre- and post-combustion capture of CO<sub>2</sub>.
- Continued concentration on identifying, validating, and testing suitable sites for safe, long-term CO<sub>2</sub> storage.
- By 2015, build on R&D advancements in IGCC and CCS technologies achieved over the past five years to at least double the amount of carbon dioxide sequestered, compared with earlier goals.

# THE COMMITMENT TO CLEAN COAL

- The National Energy Policy Development Group (NEPDG) report recognizes coal must continue to play a key role in securing a healthy U.S. economy – between 2006 – 2030, 130 gigawatts (GW) of new coal-based generating capacity is projected to be added (Source: U.S. Energy Information Administration, *Annual Energy Outlook, 2008*).
- Recommendations include \$2 billion over 10 years for advanced clean coal technologies.
- Coal assumes a key role in Presidential-level initiatives: Climate Change, Hydrogen, Sequestration; all integrate energy policy with environmental policy.



**FOSSIL FUELS ARE PROJECTED TO REMAIN THE MAINSTAY OF ENERGY CONSUMPTION WELL INTO THE 21<sup>ST</sup> CENTURY. AVAILABILITY OF THESE FUELS TO PROVIDE CLEAN, AFFORDABLE ENERGY IS ESSENTIAL FOR GLOBAL PROSPERITY AND SECURITY.**

## MEETING 21ST CENTURY NEEDS

### SHORT-TERM

- Maximize existing plants;
- Provide advanced technologies for new, near-term plants;
- Provide technology bridge to transition to future plants.

### LONG-TERM

- Near-zero emissions, including CO<sub>2</sub>;
- Increased reliability, cost competitive;
- Technology for hydrogen economy.



## COAL'S CONTINUED IMPORTANCE IN THE YEARS AHEAD

ELECTRICITY DEMAND IN 2030 WILL BE 39 PERCENT HIGHER THAN TODAY.

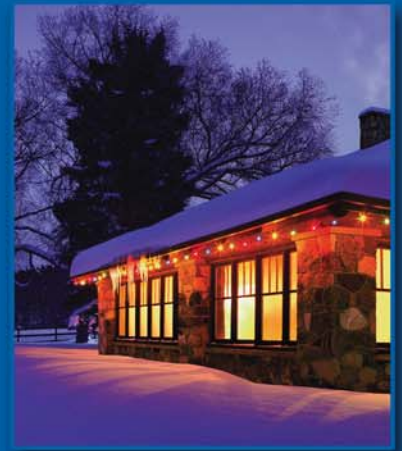
MEETING THE DEMAND WILL REQUIRE AT LEAST 139 GIGAWATTS OF NEW COAL CAPACITY — HALF OF ALL PROJECTED NEW CAPACITY.

COAL'S SHARE OF ELECTRIC GENERATION WILL RISE TO 57 PERCENT.

# PRODUCING RESULTS



THE FIRST COAL GASIFICATION ELECTRIC POWER PLANTS ARE NOW OPERATING COMMERCIALY IN THE UNITED STATES AND OTHER NATIONS AND MANY EXPERTS PREDICT THIS TECHNOLOGY WILL BE THE BASIS FOR CLEAN COAL TECHNOLOGY PLANTS WELL INTO THE FUTURE.



- Work is moving forward under the Coal Research Initiative (CRI) in DOE's Office of Fossil Energy — its purpose: Advance a range of technologies for improved pollution control, higher efficiencies, and carbon capture and sequestration.
- The Clean Coal Power Initiative (CCPI) demonstrates technology advances, including an initiative to equip multiple clean coal power plants with advanced carbon capture and storage technologies.
- In the first two rounds of CCPI, participants offered to match every federal dollar with an average \$5 from the private sector.
- More than \$1 billion in tax incentives authorized by the Energy Policy Act encourage investment in integrated combined cycle, gasification, and other advanced coal projects, fostering their early and wide commercial deployment.

## THE CLEAN COAL POWER INITIATIVE

*The Clean Coal Power Initiative* is a cost-shared partnership between the government and industry to develop and demonstrate advanced coal-based power generation technologies that can help utilities cut sulfur, nitrogen, and mercury pollutants from power plants by nearly 70

percent by 2018. Along with cutting-edge carbon capture and storage, these clean coal technologies will enable the United States to continue to benefit from clean, reliable, and affordable electricity and power from coal, our most abundant energy resource.



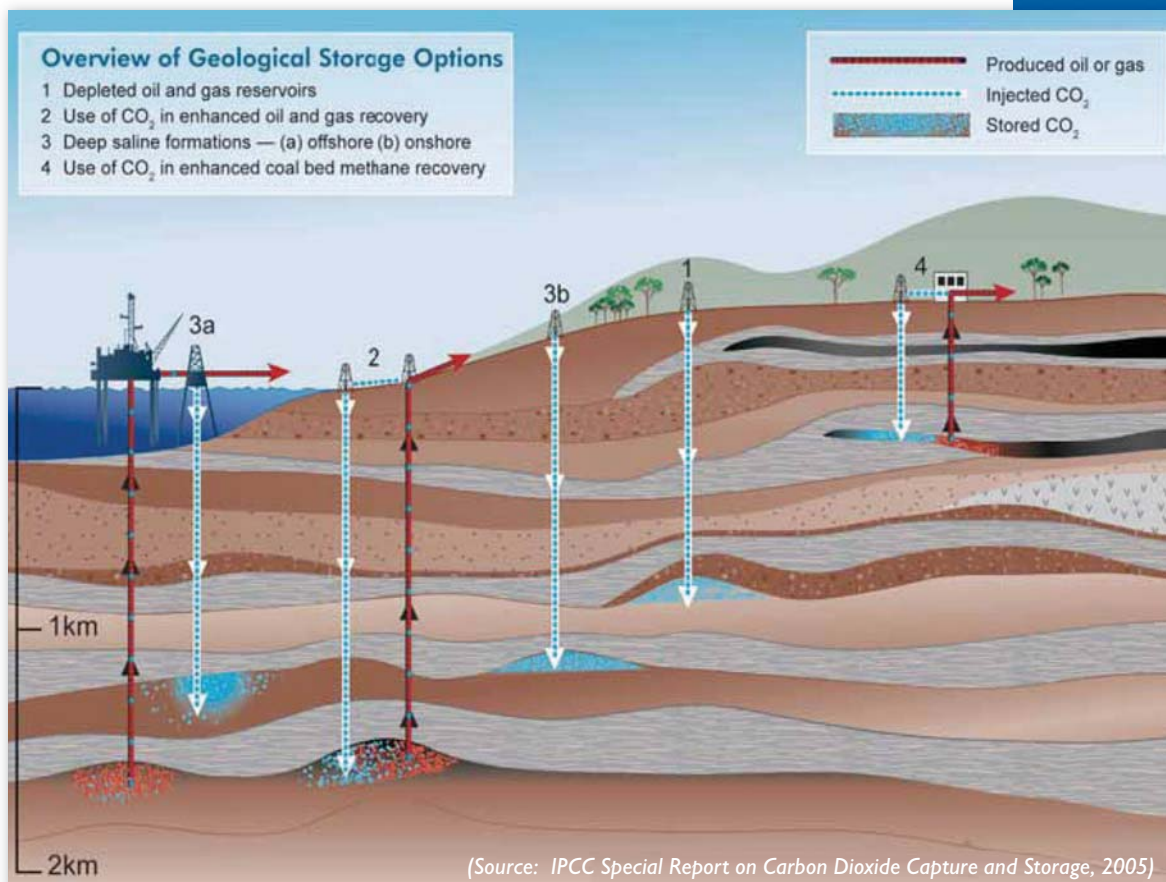
## CARBON SEQUESTRATION KEY GOALS

- To develop by 2012 fossil fuel conversion systems that offer 90 percent CO<sub>2</sub> capture with 99 percent storage permanence at less than a 10 percent increase in the cost of energy services.
- The portfolio of technologies being developed through government and industry partnerships applies to both newly built systems and also retrofits of existing equipment.

## REGIONAL CARBON SEQUESTRATION PARTNERSHIPS

- Involves 40 states, 4 Canadian provinces, hundreds of stakeholders.
- Initial efforts identified potential geological storage for 600 gigatons of CO<sub>2</sub> – capacity enough to hold several centuries' worth of U.S. power emissions.
- Additional funding over the next 10 years will advance the work of the regional partnerships, supporting multiple large-scale tests of geologic sequestration.

CARBON SEQUESTRATION, THE IDEA OF CAPTURING CARBON DIOXIDE BEFORE IT IS EMITTED TO THE ATMOSPHERE AND STORING IT IN UNDERGROUND ROCK FORMATIONS OR OTHERWISE SEQUESTERING IT, HAS PROGRESSED STEADILY OVER THE PAST 10 YEARS. IT IS NOW POISED TO BECOME A KEY TECHNOLOGY OPTION FOR GREENHOUSE GAS EMISSIONS ABATEMENT.



For more information about the Office of Fossil Energy's Clean Coal Technology Program, please visit

[WWW.FOSSIL.ENERGY.GOV](http://WWW.FOSSIL.ENERGY.GOV)



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