



Strategic Plan

*Planning for Sustainable
Development*

MISSION

The mission of the Coal and Power Systems RD&D Program is to foster the development and deployment of advanced, clean, affordable fossil-based power and alternate fuels systems. Fuel-flexible power generation and conversion technologies will be developed to efficiently utilize coal, natural gas, opportunity fuels, and other feedstocks. The long-term focus is on the effective utilization of coal — the Nation's most abundant energy resource — and natural gas. Government-sponsored research in partnership with industry, laboratories, and academic organizations will promote U.S. global leadership in coal fuels and power system technologies, creating U.S. jobs and contributing to a stronger economy.

VISION TO 2015

Economically viable technologies will be available for clean production of low-cost electricity, and low-cost fuels from coal will raise global living standards for future generations. As the leader in developing ultra-high-efficiency energy technologies with near-zero emissions, the United States will benefit from plentiful, low-cost electricity supplies and alternative fuel sources. The United States will produce a significant share of the products and services being used in the fast-growing world energy market while enhancing its trade balance, and creating highly skilled, well-paying jobs.

INTRODUCTION

Driven by changes such as deregulation of power generation, more stringent environmental emissions standards, and increased competition among fuels, the energy industry is undergoing a major transformation.

With these changes come new participants, and perhaps a refocusing by organizations in providing energy services and products. The traditional concepts of how energy (both electricity and fuel) is produced, transported, and utilized are likely to be very different in the coming decades. As market, policy, and regulatory forces evolve to shape the energy industry (both domestically and globally), there is a need for clean, low-cost energy options; competitively priced fuels; and low-cost, environmentally compliant power systems. These benefits will be realized through the broad commercial deployment of advanced fossil technologies.

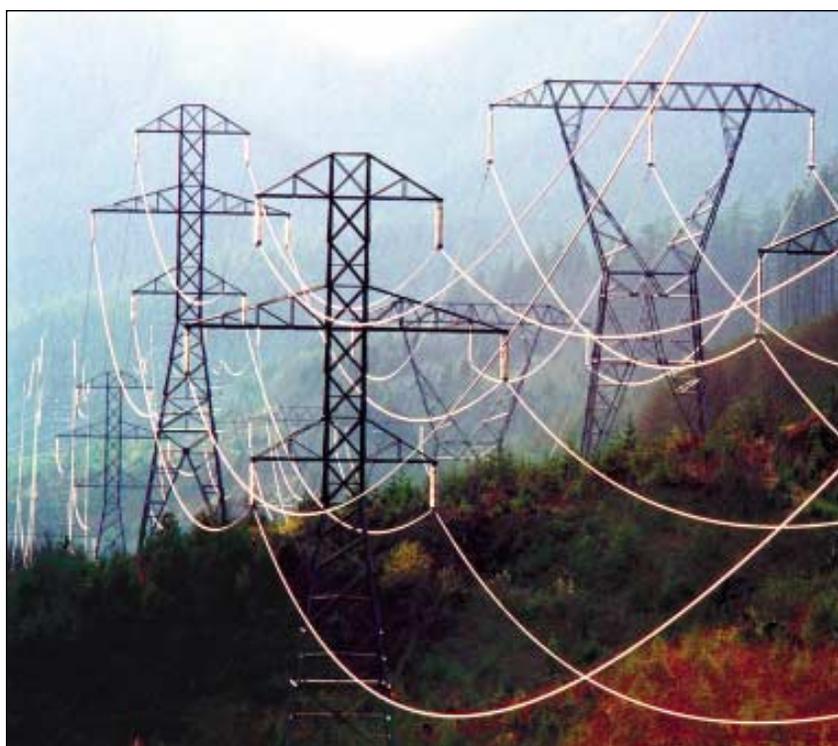
Fossil fuels are and will continue to be the primary source for power generation and fuel systems. The role of the Federal Government will be to provide support in developing advanced fossil energy technologies that ensure continued environmental and economic benefits. The C&PS Vision 21 concept allows the Nation to realize the full potential of its abundant fossil fuel resources by maintaining and strengthening the integral role of fossil fuels in the Nation's energy mix. Vision 21 is the long-range strategic vision of where coal and power systems will be in 2015 and beyond. Vision 21 is a new approach to clean, efficient energy production from fossil fuels in the 21st-century. It will integrate advanced concepts for high-efficiency power genera-

tion and pollution control into a new class of fuel-flexible facilities capable of producing electric power, process heat, and high-value fuels and chemicals with virtually no emissions of air pollutants. In doing so, Vision 21 can create the opportunity for long-term, clean, and efficient use of natural fuel resources to meet ever growing energy demands while stabilizing greenhouse gas emissions.

The following plan describes how DOE intends to advance the efficient, affordable, and environmentally effective use of domestic coal, gas, oil, renewable, and other opportunity fuels. It is a plan based on the consensus of

experts and managers from the Department's Fossil Energy headquarters program offices and the National Energy Technology Laboratory (NETL). The C&PS plan reflects a broad cross-section of stakeholder and customer input and recommendations. The overall process takes into consideration the current situation, challenges, and drivers.

In relation to other plans, the C&PS Plan is derived from the Fossil Energy Program's strategy, mission, and vision. The Fossil Energy Program, in turn, supports DOE's mission and its Energy Resources strategic goal "to develop and promote secure and competitive energy systems that minimize impacts on the U.S. and the global environment." The next series of sections in the document, following the C&PS Strategic Plan, are the Coal and Power Systems Program Plans which contain more detailed descriptions of program activities and milestones.



SITUATION ANALYSIS

Current Situation

The United States has the lowest unsubsidized electricity rates in the world. This is largely due to using a diversity of fuels and placing the greatest reliance on the most abundant and lowest cost fuel, coal. Coal currently provides 53 percent of the Nation's electricity, while natural gas, oil, nuclear, and renewables contribute 14, 3, 18, and 12 percent respectively.

U.S. consumption of petroleum, half of which is imported, is driven primarily by the transportation sector, which relies on the commodity for nearly 97% of its energy.

However, the role of traditional energy technologies and use has shifted substantially in the last two decades. The nuclear contribution to electricity production continues, but at a reduced rate because of plant retirements and the lack of new additions since 1973. Public and regulatory pressures have prevented new plants from being built, and plants approaching relicensing face much the same pressure in addition to being forced to compete in an open market under utility restructuring. As a result, more than half of the existing nuclear generation capacity is projected to retire by 2020. The renewables element consists primarily of hydroelectric power, which represents 88 percent of total renewables generation. Hydroelectric power, however, having to address a host of environmental concerns, has remained essentially constant over

the past decade. And while diversity of import sources has increased, oil price is still largely determined by regions subject to political instability.

Coal-fired generation, which has dominated the electric power sector since early this century and still accounts for over 50 percent of the electricity production, is being affected by more stringent



and new environmental regulations that will result in added compliance costs. As a result of these factors, coupled with higher capital costs and significantly longer construction lead times relative to gas-fired generation plants, coal is no longer the first choice for plant capacity additions. Natural gas use in electricity generation has steadily increased over the last decade to provide power during peak demand periods. With its relatively low price and plentiful supply, natural gas is expected to dominate new U.S. plant capacity in the near term.

There have also been dramatic changes in the market structure of the electricity sector. Roughly

one-half of the states have adopted legislation to deregulate their electric utilities, thus opening their electricity market to retail competition. Many more states are considering restructuring, and federal legislation has been proposed that would mandate nationwide open access. One of the consequences of retail competition is increased competition for market share in the fuel and power

technologies sectors. The near-term convergence of utility deregulation and increased environmental concerns has shifted investment away from long-term fuel and power technology RD&D to those with short-term payoffs. In addition, concerns over carbon emissions and their potential impact on global climate change have created an added measure of uncertainty relative to investment in coal-based plants.

Future Trends

The DOE Energy Information Administration's (EIA) "Annual Energy Outlook 2000" projects that U.S. reliance on fossil fuels will rise from the present level of 85% to 90% by 2020 under current trends of price and usage. The EIA also projects that the use of fossil fuels to produce electricity will rise from the current 67% to 78% by 2020. Approximately 225,000 MW of new electricity generating capacity is expected to be required by 2010. Of this, 50% will be gas-fired peaking units, and 40% will be gas combined-cycle. In addition to the EIA projections, the existing fleet of coal-based power generation is aging and much of it will be nearing end of life by 2020.

By 2020, U.S. petroleum imports, already representing over 50% of consumption, is projected to rise to 65% and increase our negative balance of payments. Total worldwide petroleum demand will double, creating a very competitive market for increasing amounts of imports from sources that may be politically unstable. The challenge is to provide the technical basis for a clean fuels industry capable of producing transportation fuels from coal and other carbonaceous, non-petroleum domestic resources.

Of greater interest though, is energy consumption in the developing world (Asia, Africa, the Middle East, and Central and South America), which is expected to more than double by 2020, with the highest growth rates expected in developing Asia and Central and South America. In fact, energy use in the developing world is projected to surpass that of the industrialized world by 6 percent

in 2020 — some 16 quadrillion Btu — whereas in 1996 energy consumption in the developing countries was about 40 percent lower than that in industrialized countries.

Opportunities abound for enhanced economic prosperity, with the challenge lying in providing the energy to sustain both economic and population growth while addressing global and regional environmental concerns. Fossil energy is the only means of fueling the tremendous worldwide economic growth envisioned over

the next two decades. As much of the world makes the transformation to industrialization, electricity represents an increasingly large part of the energy requirement. C&PS is responding to these realities by introducing, and continuing to improve upon, a new generation of more efficient, affordable, and environmentally friendlier fossil fuel systems. With much of the developing world planning to use fossil fuels, particularly coal, the deployment of high efficiency fossil systems is key in the approach to addressing global climate change concerns.



THE CHANGING ENERGY LANDSCAPE

Environmental Challenges with Fossil Fuels

To meet world energy demands into the foreseeable future, coal must play a significant role, particularly in electric power generation. But, coal faces the challenge of controlling pollutant emissions associated with its use, as well as mitigating the greenhouse gas emissions. Almost all coal-using countries have developed standards to deal with particulate matter, nitrogen oxides (NO_x), and sulfur dioxide (SO_2) emissions from coal-fired plants.

Now, given potential regulatory requirements for NO_x , SO_2 , hazardous air pollutants (HAPs), ozone, fine particulates, and solid and liquid wastes, the Nation must find cost-effective ways to implement environmental protection regulations.

Global Energy Concerns

World carbon emissions are expected to reach 8.0 billion metric tons by 2010 and 9.8 billion metric tons in 2020. In developing countries, carbon emissions are projected to grow more quickly. Emissions from the developing countries were about 60 percent of those from the industrialized countries in 1990, but by 2010 they will surpass them. The sharp increase is expected to be caused both by rapid economic growth, accompanied by growing demand for energy, and by continued heavy reliance on coal — the most

carbon-intensive of the fossil fuels — especially in developing Asia.

International concerns over the future impacts of greenhouse gases produced by anthropogenic activities have led to an international consensus that cost-effective measures to reduce the growth of greenhouse gas emissions are prudent. Some nations remain concerned about the uncertainties of potential longer-term (2100 and beyond) impacts. Domestic and international sources are also pressing for large absolute reductions in the near term. Technologies being developed to allow the use of indigenous resources must address these concerns.

Electric Utility Deregulation

Utility restructuring has begun, with half of the states adopting legislation, the other half contemplating legislation, and the Federal Government deliberating legislation. The uncertainties associated with utility restructuring have exacerbated concerns over the reliability and quality of electric power delivery. Reserve margins are shrinking as energy suppliers increase capacity factors on existing plants, rather than install new capacity to meet growing demand. This increases the probability of forced outages and reduced power quality. Utility restructuring also shifts the burden of financing new energy ventures from the consumer to the power supplier. This favors less capital-intensive projects and projects that can be permitted and constructed in the shortest possible time, including smaller, modular power systems for the distributed generation and combined heat and power markets.



PLANNING ASSUMPTIONS

Challenges to Technology Deployment

- Maintaining low-cost electricity domestically in the face of unprecedented growth in demand and increasing environmental pressure requires new technology capable of using the Nation's clean natural gas resources more efficiently, utilizing coal (our most abundant and lowest cost resource) cleanly and efficiently, and expanding the resource base to include other feedstocks and opportunity fuels.
- Supporting the R&D necessary to achieve widespread deployment of new technologies with reduced investments from industry requires an expansion of public/private sector partnerships, a focusing of R&D efforts, and introduction of new approaches to mitigate development costs.
- Ensuring the availability of reasonably priced transportation fuels vital to national security and economic stability with increased worldwide pressure on crude oil resources requires a capability to reduce dependence on imports through development of an alternative fuel capability reliant upon domestic resources.
- Providing reliable, quality electric power under utility restructuring, and increasing demand for electricity requires a portfolio of distributed power generation technologies (including combined heat and power, or CHP).



- These must be capable of installation at or near user sites to relieve transmission and distribution (T&D) constraints and satisfy customers particularly sensitive to outages, harmonics fluctuations, and voltage spikes associated with T&D systems. Power quality and reliability may become much more important with the emergence of “e-commerce.”
- Responding effectively to global climate change concerns in view of the tremendous worldwide energy growth envisioned requires the development and deployment of fossil-fuel based technologies characterized by

high efficiency and the ability to use a variety of fuels, including wastes and biomass; and requires affordable options for carbon sequestration.

- Providing the technology base to overcome crosscutting technical barriers that could prevent advanced power and fuels systems from contributing to the Nation's energy future.
- Capturing a significant share of the global market will require continued R&D support and deployment incentives. This will provide the necessary leverage to offset direct subsidies provided by other governments.



In this design coal and municipal waste are delivered to the feed system by barge. Lime, the sorbent material, is added to the feedstock to capture and remove sulfur released during combustion.

VISION 21: C&PS RESPONSE TO THE CHALLENGE

The rapidly changing domestic and international situation (i.e., climate change, oil security, environmental regulation, electric utility restructuring, aging U.S. energy infrastructure, global trade competition and privatization, and declining R&D budgets) requires that more be done. Vision 21 combines electricity- and fuel-producing subsystems being developed by the C&PS Programs in a way that seeks to maximize thermal efficiency, minimize emissions of traditional pollutants, and minimize cost, all while being readily compatible with carbon dioxide sequestration.

Vision 21 is a new approach to 21st century energy production from fossil fuels. It will integrate advanced concepts for high-efficiency power generation and pollution control into a new class of fuel-flexible facilities capable of producing electric power, process heat, and high-value fuels and chemicals with virtually no emissions of air pollutants. These plants will be designed using a variety of configurations to meet differing market needs. Vision 21 builds on the Clean Coal Technology Program experience and a portfolio of advanced technologies already being developed — including IGCC, PFBC, advanced gas turbines, fuel cells, and fuels synthesis — and adds other critical technologies and system integration techniques.

This concept is a vision of the way electricity needs to be generated in

the 21st century in order to meet environmental requirements and keep energy costs affordable and consistent with robust economic growth. Vision 21 goals align directly with FE and DOE strategic goals to provide economical, and environmentally benign fuels and technologies that will promote domestic security as well as establish a leading international market presence. The Vision 21 concept and goals are interwoven throughout all C&PS Program Areas. An aggressive industry cost-shared Vision 21 approach would:

- **Remove environmental barriers to fossil fuel use.** The technological innovations produced by the C&PS Program will allow use of a balanced mix of fossil fuels for our electricity and transportation fuels needs. Environmental barriers, including smog- and

acid-rain-forming pollutants, will be effectively removed. Concerns over global climate change will be mitigated by carbon dioxide emission reductions as great as 50% resulting from thermal efficiency improvements. Net CO₂ emissions can be reduced to near-zero, if needed, through sequestration.

- **Keep energy costs affordable.** Without the technological innovations brought about by the C&PS Program, use of low-cost fossil fuels is likely to be severely curtailed by environmental pressure, particularly global climate change concerns.

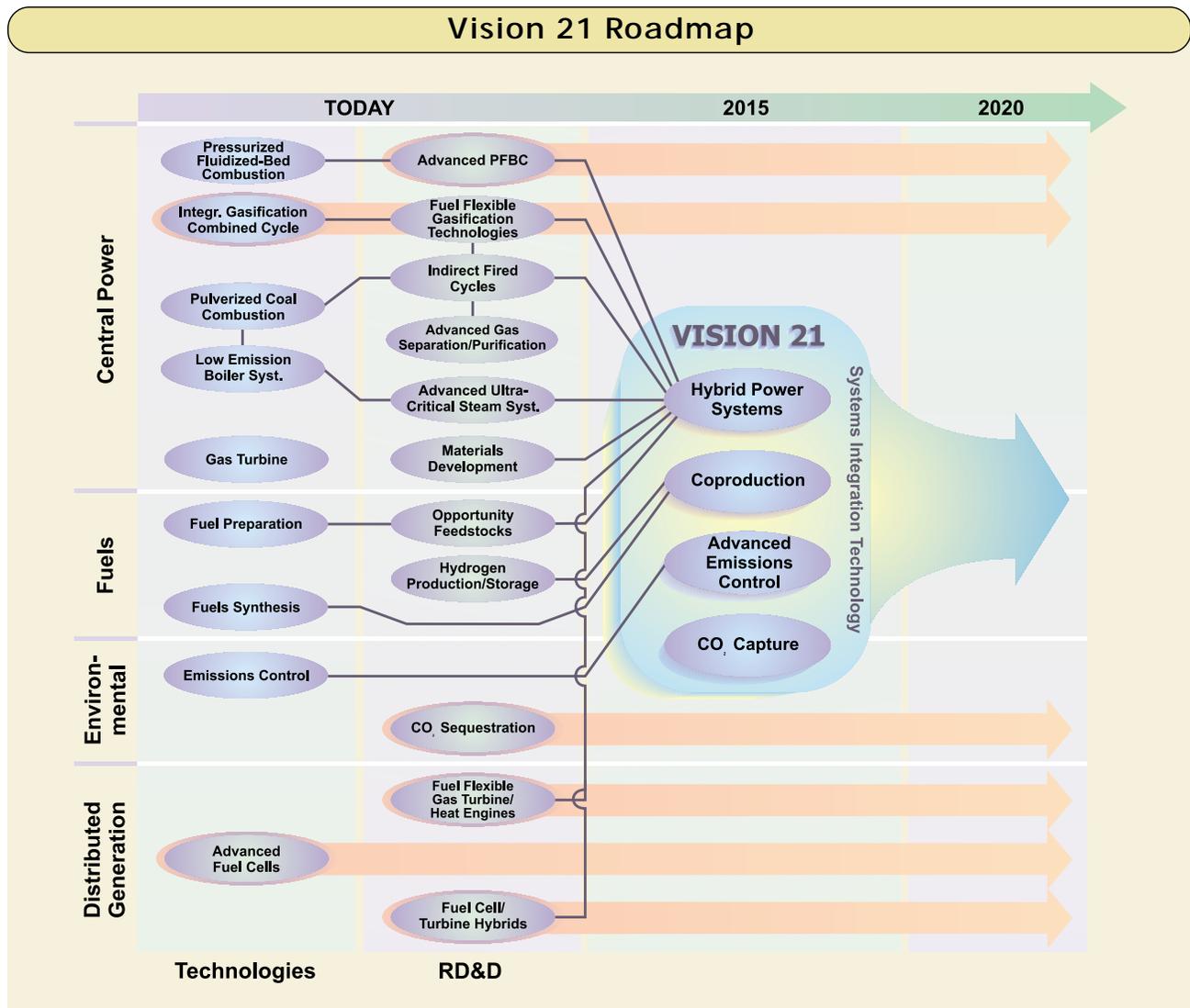
This will leave the United States with a substantially narrowed range of much higher cost energy options, which may limit the full potential for achieving sustained economic growth and prosperity.

- **Produce useful coproducts, including transportation fuels.** Vision 21 assures the U.S. of the availability of transportation fuels that are cost-competitive with equivalent petroleum products. National security is increased because reliance on imported oil is reduced. The international balance of trade is improved because oil imports can be reduced and also because

the availability of alternative sources of transportation fuels tends to stabilize oil prices.

- **Continue U.S. leadership role in clean energy technology.** By a recently published account, world trade in environmental controls has surpassed trade in armaments. Vision 21 will create the U.S. technology and know-how to promote the export of fossil energy technology, equipment, and services. U.S. fossil energy/environmental industries will expand and new industries will be created, providing local, regional, and national benefits.

Vision 21 Roadmap



GOALS, OBJECTIVES, STRATEGIES, AND PROJECTED BENEFITS

The strategic plan for the C&PS Program pursues its mission and vision through goals which fall under the categories of:

- Clean, efficient, and competitive energy systems;
- Energy security; and
- International.

These goals, associated objectives, and strategies are summarized in Table 1, along with projected benefits that help determine progress toward meeting the goals and objectives, and ultimately, Vision 21.

TABLE 1: GOALS, OBJECTIVES, AND STRATEGIES FOR COAL AND POWER SYSTEMS RD&D

Goal 1: Clean, Efficient, and Competitive Energy Systems — Promote reliable, affordable electricity supplies that are generated with acceptable environmental impacts.

Objective 1: By 2008, develop and deploy in initial markets key enabling advanced power technologies, including fuel cells, turbines, and gas separation membranes. Thereafter, progressively enhance these technologies for use with multiple feedstocks, to achieve near-zero emissions of traditional pollutants, to almost double the average fleet efficiency of today's operating power plants, and to be compatible with carbon sequestration systems. The enhanced technologies will be commercially available for integration into a new generation of fossil fuel-based systems by 2015.

- **Strategy 1:** Complete the development of a suite of power systems, including PFBC, IGCC, indirect fired cycles, turbines and combined cycles for application in central power generation.
- **Strategy 2:** Integrate advanced power modules with other advanced fossil systems to achieve a "Vision 21" fleet of plants that can maximize economic, energy, and environmental efficiency through the use of multiple carbon-based feedstocks, and production of a competitive mix of electricity, fuels and/or chemicals.
- **Strategy 3:** Foster the development of small generating units, focusing on fuel cell and fuel cell/turbine hybrids under 30 MWe, at or near consumer sites to meet specific customer needs.

Objective 2: By 2015, develop low-cost carbon sequestration technologies that can be integrated with advanced fossil fuel systems that will be commercially available in the same timeframe.

- **Strategy 1:** Develop low-cost technology options for CO₂ management which would include capture, separation, use and disposal.

Objective 3: Between 2003 and 2008, provide technologies to improve the environmental performance of existing coal-fired powerplants and reduce compliance costs by 25-75%, compared to existing technologies and strategies.

- **Strategy 1:** Enhance the technical performance of environmental control systems to meet pending environmental regulations, including those associated with small particulates (PM2.5), reduction for ozone attainment, and hazardous air pollutants.
- **Strategy 2:** Minimize the volume of coal combustion by-products through the use of industrial ecology principles.

Goal 2: Energy Security — Promote reliable, affordable, clean and diverse domestic fuel supplies.

Objective 1: Provide the Nation with lower-polluting alternatives to liquid transportation fuels that are cost-competitive with equivalent petroleum products for deployment by 2010.

- **Strategy 1:** Produce high-quality, clean burning fuels (“ultra-clean fuels”) from coal and other carbonaceous feedstocks, including fuels that will enable the use of high-efficiency, low emissions engines being developed in DOE’s Partnership for a New Generation of Vehicles and heavy truck programs .

Goal 3: International — Cooperate globally on international energy issues.

Objective 1: Establish effective partnerships to expand the use of clean, efficient, fossil energy-related technologies and energy services.

- **Strategy 1:** Cooperate with other countries to develop and demonstrate advanced technology.
- **Strategy 2:** Help open foreign markets to U.S. companies through cooperation with foreign governments and international institutions to develop energy sector laws, policies and regulatory processes for setting standards and enforcing regulations.

STRENGTH THROUGH SCIENCE...

A "GREENER, SOONER" PHILOSOPHY

In the coming century when energy demand will continue to rise in this country and the world, DOE's Office of Fossil Energy through the Office of Coal and Power Systems is building toward:

- **A pollution-free power plant.** A plant that emits no airborne pollutants, no solid wastes, no wastewater, perhaps no greenhouse gases. A power plant that has no negative impact on the environment.
- **A technology that captures and stores carbon dioxide** and other gases that can cause global warming. A way to remove greenhouse gases from the exhausts of energy facilities or directly from the atmosphere on a massive scale at costs both developed and developing nations can afford.

The essence of the C&PS Programs is a continued emphasis on cleaner, more efficient, lower cost use of our traditional fuels - an emphasis that can keep our economy growing, provide a cleaner, healthier environment, and enhance the country's energy security.

A "greener, sooner" strategy means that the country does not have to wait for the promising energy contributions from renewables and other alternative fuels. By applying technological advances, the U.S. can continue to improve environmental quality and reap the economic benefits of the fuels this country counts on most while alternative energy sources move into the market.

By focusing its activities on the research and development of supporting technologies for Vision 21 together with carbon sequestration R&D, C&PS is taking the lead on meeting the energy and environmental challenges of the next century, while at the same time making the economy stronger.

- **Vision 21 – The Power Plant of Tomorrow.** The pollution-free power plant of tomorrow, termed Vision 21, could be fueled by coal or natural gas, perhaps combined with biomass or even the discarded wastes of cities. Vision 21 builds on technology advancements being made in DOE's Fossil Energy Program. It will integrate ongoing research and development in advanced coal and biomass gasification and combustion with next-generation fuel cells, high performance turbine technology, and advanced coal conversion systems.
- **Carbon Sequestration – A Climate Change Solution.** DOE has set a goal of removing carbon dioxide from the exhausts of energy plants or from the atmosphere itself, permanently storing or recycling it at costs as low as \$10 per ton of carbon, equivalent to only 2/10ths of a cents per kilowatt-hour in the cost of electricity. At these low costs — and because no massive overhaul of today's energy infrastructure would be required — sequestration could offer a climate change solution that both industrialized and developing nations could afford.

PROGRAM BENEFITS

Investments made in C&PS programs by government and industry are projected to reap enormous environmental, economic, and energy security benefits. The combined benefits of the Central Power, Distributed Generation, and Fuels Programs are expected to result in the creation of almost one million jobs per year and cumulative economic benefits of almost \$1.25 trillion by 2030; almost \$300 billion in benefits accrue in the period from 2026 to 2030 alone. By 2030, carbon emission reductions through technology advancements developed in the Advanced Research and CO₂ Sequestration Programs will reduce U.S. carbon emissions by more than 200 million metric tons per year compared to conventional technology. Tables containing a detailed summary of projected economic benefits and carbon emission reductions to 2030 are shown below.

BENEFIT TO U.S. ECONOMY

Benefits from domestic and international sales of more efficient coal and gas-power systems¹ will reduce fuel costs to the industry and result in lower fuel use to generate the same amount of electric power. Advanced systems are being developed to significantly reduce emissions by 2015 by: (1) developing market-ready coal power systems with efficiencies over 60

¹ Benefits begin in 2005 for gas-fired systems and 2015 for coal-fired systems.

percent and near-zero emissions; and (2) integrating advanced turbine and fuel cell technology to achieve market-ready gas-fueled powerplants with efficiencies over 70 percent. Potential benefits from these technologies are cost of electricity savings of \$1 billion per year by 2015, reaching \$5 billion per year in 2030; generating more than 800,000 jobs per year by 2030; and contributing to powerplant sales of \$20 billion per year in 2030. The cumulative economic sales to both domestic and international markets will amount to almost \$300 billion dollars over the forecast period.

EFFECT ON U.S. AND GLOBAL MARKETS

Cost-competitive advanced technologies will equip U.S. manufacturers to capture a significant share of U.S. and global markets for power generation equipment. For the 30 years leading up to 2030, domestic sales are expected to have an economic impact of about \$110 billion and generate almost 400,000 jobs per year in 2030. During the same time period, international sales could potentially bring in revenues of almost \$180 billion, and could support over 400,000 jobs per year by 2030.

REDUCED DEPENDENCE ON FOREIGN OIL

A U.S. coal-conversion industry could reduce dependence on foreign oil supplies, thus increasing the Nation's oil security while helping reduce the U.S. energy trade deficit. Benefits from the Fuels Initiative (referred to as Cumulative Production Capacity of Ultra Clean Fuels) include

development of advanced fuels from the coal transportation-fuels and the gas-to-liquids programs. Advanced fuels development will provide over 110,000 jobs per year by 2030 and contribute over \$8 billion per year to the U.S. balance of payments.

ENVIRONMENTAL SYSTEMS IMPACTS

The most significant macroeconomic benefits to the U.S. will be the result of cost reductions of compliance with environmental regulations due to C&PS environmental retrofit technologies. Technologies are being developed to enable existing coal-fired powerplants to comply with ozone and PM2.5 ambient air quality standards at lower cost. Potential savings total \$2.4 billion/year for NO_x control by 2005 and \$2.1 billion/year for SO₂ control by 2008. Technologies being developed to meet projected mercury emission standards² have potential savings of \$4.2 billion/year by 2008. These technologies will reduce the cost of conventional compliance with SO₂, NO_x, and mercury emissions environmental regulations by 50 – 90%. These environmental retrofit technologies will result in almost \$205 billion in cumulative cost of compliance savings over the forecast period.

Ultra-clean fuels will enable the efficiency of conventional vehicle systems to be more than doubled with the resultant benefit of significantly lower carbon dioxide emissions. Production of one million barrels per day of ultra clean fuels is estimated to reduce

² Mercury emission regulations are expected to be mandated between 2005 and 2008.

carbon emissions by approximately 20 million tons per year. Globally, deployment of advanced power systems and ultra-clean fuels will reduce carbon emissions by more than 600 million metric tons per year. Total cumulative carbon reduction throughout the forecast period will be more than four billion metric tons.

BENEFITS TO THE CONSUMER

The C&PS investment in both advanced power system technology for new generating capacity, and the environmental retrofit of existing power plants will result in a significant reduction in fuel cost and environmental compliance costs for U.S. utilities. The reduction in capital requirements to the utility industry could result

in the use of this capital for more productive uses in the economy including stimulating growth in employment and income.

A reduction in a utility's operating and maintenance expenses, the savings on capital, and lower fuel costs will likely result in a utility's ability to provide lower, more competitive electricity prices to consumers. In fact, C&PS investment in new technology to reduce the cost of pollution abatement

Benefits Projection of Fossil Energy's Coal and Power Systems Programs

	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
Domestic Power System Capacity — Coal & Gas (GW/5yr)	0	46	59	60	94	142
Commercialization of Power Systems (\$mm/5 yr)	0	8,318	10,639	12,955	30,080	48,451
Jobs Created (jobs/year)	0	68,208	87,238	106,233	246,653	397,301
Foreign Power System Capacity (GW/5 yr)	21	69	151	155	148	152
Commercialization of Power Systems (\$mm/5 yr)	2,987	11,581	26,362	39,335	46,593	52,828
Jobs Created (jobs/year)	9,826	80,299	201,505	307,883	382,067	433,186
Cumulative Production Capacity of Ultra Clean Fuel (mmbbl/day)	0	0.18	0.51	0.69	0.80	0.90
Balance of Payments Savings (\$mm/5 yr)	0	1,375	4,031	5,632	6,778	8,153
Jobs Created (jobs/year)	0	43,054	71,624	81,557	94,762	110,211
Macroeconomic Benefit of Lower Priced Electricity (\$92 chain weighted)						
Contribution to GDP (\$mm/5 yr) (Cumulative Change from Base)	7,510	84,840	162,070	153,360	142,090	142,090
Jobs Created (jobs/year)	44,000	56,000	180,000	110,000	8,000	8,000
Direct Employment in C&PS R&D Program						
Dollars Invested in R&D (\$mm/5yr)	3,982	3,982	3,982	3,982	3,982	3,982
Jobs Created (jobs/year)	32,654	32,654	32,654	32,654	32,654	32,654
Environmental Compliance Cost Savings Due to R&D						
Dollars Saved (\$mm/5 yr)	0*	30,900	43,500	43,500	43,500	43,500
Total Impact of FE C&PS Programs						
Economic (\$mm/5 yr)	14,479	140,997	250,584	258,764	284,294	299,004
Jobs Created (jobs/year)	86,480	280,215	573,021	638,328	764,136	981,352

*Significant environmental benefits from prior years not presented, just investments after 2000.

equipment along with its investment in more efficient technology for new power generating stations is projected to save each household approximately 4 – 5% off its annual energy bill by 2010. The lower price of electricity could allow residential, commercial, and industrial electricity consumers to reduce their expenditures on electricity consumption, allowing them to save money and/or increase consumption.

These electricity savings would have a strong and pervasive effect on the economy. The reduced

cost of electricity could allow for additional expenditures on other products and/or additional savings to fund investment in the economy. This, in turn, could increase employment and production in other industries.

Macroeconomic impacts of the advanced power systems and environmental retrofit technologies over the period 2005 to 2025 include:

- A cumulative increase in real GDP of nearly \$550 billion. On a per-capita basis, the cumulative

improvement exceeds \$1800 per person or \$7200 per family of four.

- An additional increase in employment of almost 100,000 jobs each year on average.

For consumers, a lower electricity bill simply means more disposable income. The increase in individual household income could be used to supplement additional clothing, food, and housing expenditures and/or increase household savings, thus increasing the standard of living.

Projected Carbon Emission Reductions from Coal and Power Systems Programs*

	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
U.S. Carbon Emissions Reductions (high efficiency technology plus sequestration)						
<i>Coal Power</i> — MMT/yr	0	0	0	10	70	175
— Cumulative	0	0	0	25	226	841
<i>Gas Power</i> — MMT/yr	0	2	5	13	26	43
— Cumulative	0	6	25	70	168	341
Total — MMT/yr	0	2	5	23	96	219
— Cumulative	0	6	25	95	394	1,182
Global Carbon Emissions Reductions (high efficiency technology plus sequestration)						
<i>Coal Power</i> — MMT/yr	0	0	0	66	218	439
— Cumulative	0	0	0	164	872	2,515
<i>Gas Power</i> — MMT/yr	0	5	14	80	114	150
— Cumulative	0	12	59	295	782	1,442
Total — MMT/yr	0	5	14	146	332	589
— Cumulative	0	12	59	459	1,655	3,958
Ultra Clean Fuels Program Higher Efficient Engine Technology						
— MMT/yr	0	2	6	10	15	19
— Cumulative	0	5	25	65	128	213
Total Carbon Emissions Reduction Due to C&CPS						
— MMT/yr	0	7	20	156	347	608
— Cumulative	0	17	84	524	1,782	4,170

*Reductions in the emissions of carbon result from the development of ultra-clean fuels and deployment of advanced natural gas and coal-fired powerplants that have thermal efficiencies much higher than conventional power plants and also have the capability to permanently sequester remaining carbon emissions.