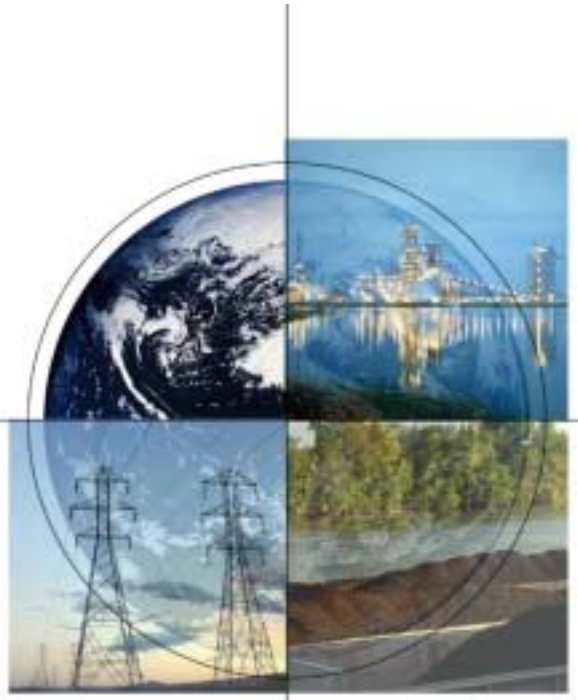
U.S. Industry Perspective on Long-Term Market Trends and R&D Needs in Gasification



National Academy of Engineering
Complements to Kyoto

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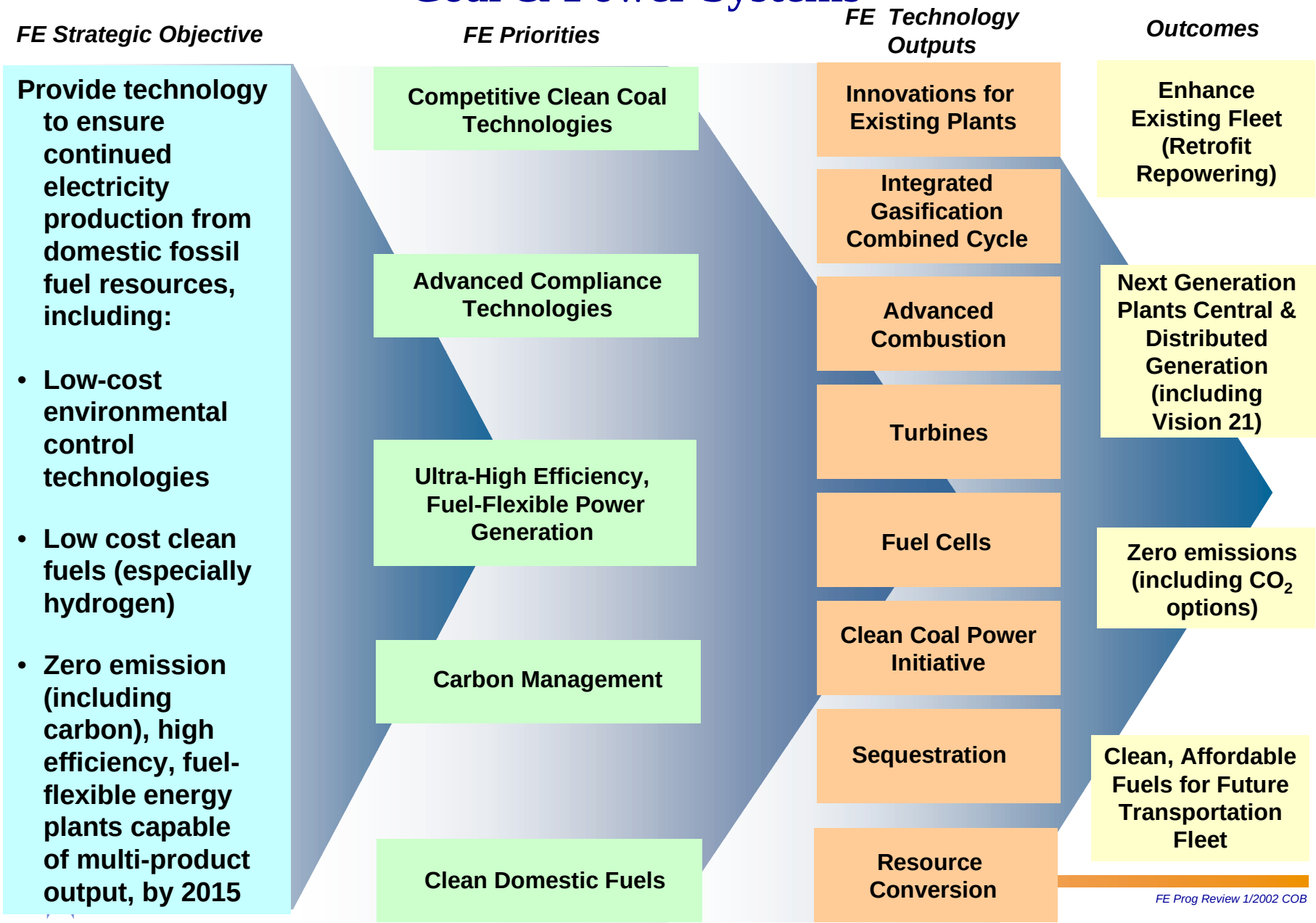
Washington, DC

John G. Wimer, Stewart J. Clayton, and Gary J. Stiegel
U. S. Department of Energy

Coal & Power Systems

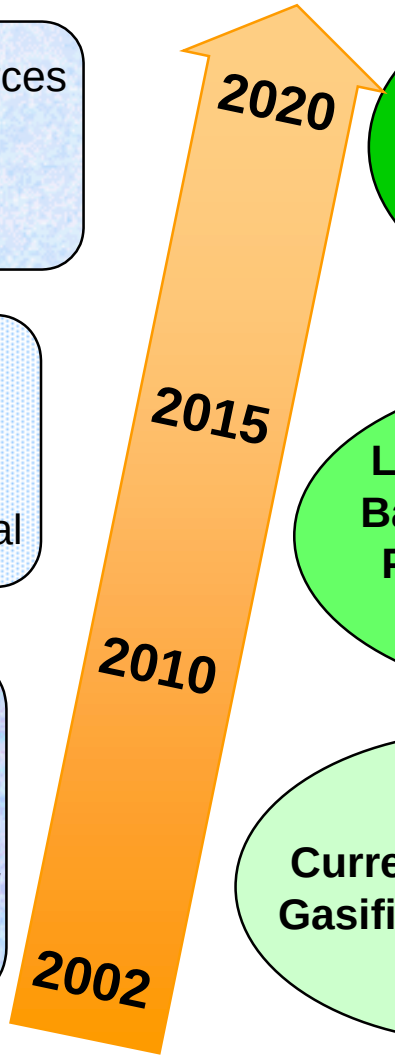


Gasification Technologies Program
Roadmap

Most economic use of domestic coal resources to generate H_2 as primary fuel with CO_2 capture for sequestration

Environmentally-Responsible Baseload Coal Power Generation
When $\$_{NG} - \$_{Coal} > \$3/MMBtu$
Co-production of multiple products from coal

Increase opportunities to use domestic coal
Disposition of solid and petroleum wastes
Lowering of costs and risks
Increase operating experience and reliability
Develop vested interests and stakeholders



Transition to CO_2 Sequestration and Hydrogen Economy from Coal

Low-to-No Emissions Baseload Coal Power Plants and Vision 21 Energy Plants

Current State-of-Art Gasification Projects

Purpose of Interviews- from a Program Perspective

- **Evaluate the current DOE gasification program**
  - Is the program focused on industry needs?
  - What should be the key issues for the program?

- **Obtain gasification industry's perspective on:**
  - Future markets and opportunities
  - Current and anticipated technology needs
  - Related environmental issues and trends
  - RD&D priorities
  - Key performance criteria

Participating Organizations

- Air Liquide
- Air Products & Chemicals, Inc.
- Allegheny Energy Supply
- Bechtel/Nexant LLC
- Citgo/Lyondell-Citgo
- Dakota Gasification Co.
- Dow Chemical Company
- Eastman Chemicals Co.
- Enron
- Fluor Daniel
- Foster Wheeler
- Gas Technology Institute
- General Electric Company
- Global Energy, Inc.
- Praxair, Inc.
- Shell Global Solutions
- Siemens-Westinghouse Power
- Southern Company
- Tampa Electric Company
- Tennessee Valley Authority
- Texaco Global Gas & Power
- UOP LLC

Gasification Markets

Factors Affecting Gasification

- **Favorable**
  - High NG prices
  - Low quality feedstocks
  - Feedstock flexibility
  - Product flexibility/market matching
  - Ultra-clean fuels
  - Superior efficiency and environmental performance (requires monetization of benefits)
  - Potential of more exacting emissions regulations
- **Unfavorable**
  - Low NG prices (commodity market uncertainties)
  - Poor reliability
  - Uncertainties in environmental regulations
  - Lack of Investor confidence
  - Real/perceived risks
  - Project cost, size, and development time
  - Large footprint
  - Public perception of coal

Short-Term Markets and Drivers (to 2008)

- **Function of steady, incremental improvements in unit economics and operation**
- **Affected by price/supply outlook for NG and portfolio diversification requirements (asset hedge against volatility)**
- **Niche opportunities**
  - Project economics, feedstock, regulation, and product integration are key drivers
  - Low cost feedstocks (petroleum coke/residue)
  - Marketable products (electricity, hydrogen, chemicals, etc.)
  - Waste recycling and disposal
- **Overseas markets, excluding Europe, not lucrative (infrastructure, project development schedules, financing)**

Transition to Long-Term Markets

- **Successful transition to long-term mainstream deployment dependent on:**
  - Continual improvement of economics, schedule and performance parameters to increase investor confidence
  - Significant improvement in reliability and availability
  - Demonstration of environmental and economic performance for disposition of hazardous wastes
  - Streamlining of environmental regulatory process
  - National grassroots educational program

Long-Term Markets (Beyond 2008)

- **Growth expected in two primary markets**
  - Clean power generation
    - Repowering – 50% of existing coal fleet over 25 years old
  - Clean energy conversion
    - Co-production of multiple products (fuels, chemicals, power)
    - Multiple feeds (pond fines, gob, biomass, industrial waste)
- **Transition to hydrogen economy**
  - Central and distributed generation (integrated with fuel cells)

Environmental Issues

Environmental Issues

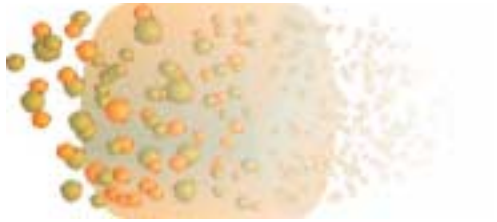
- Regulatory Uncertainties (NO_X, GHG, Hg, solid wastes)
- Development Time (Permitting)
- Misperceptions of Regulators (Gasification vs. Incineration/Combustion)
- Current environmental standards do not recognize fuel-diversity benefits
- Misperceptions of the Public

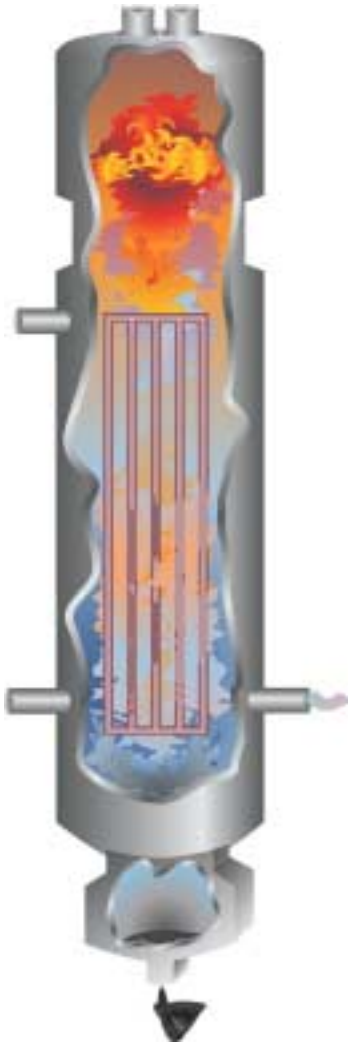
NO_x, Hg, Solid Waste, Water Issues

- **NO_x emissions may be limited to 3-5 ppm levels**
  - Increased capital cost if Rectisol and SCR required
- **Mercury regulations expected in the near-term**
  - Methodology/technology for measuring Hg not well demonstrated
  - Control technologies required
- **Solid waste**
  - Extension of proposed EPA rule for syngas from refinery waste to other industries
- **Permitting will become more difficult**
  - Zero water discharge likely
  - Trace metals limits – arbitrary and often below detectable limits

GHG Emissions

- **Uncertainty regarding the "if, when, and how" of U.S. GHG regulations**
- **Companies seriously considering GHG issue as they plan and position for the future**
  - Projects being screened for potential GHG liability
  - Gasification can benefit from GHG regulation if sequestration becomes an economic option
- **Timing and structure of GHG regulations is critical**
  - If poorly conceived, massive switch to natural gas would devastate the power and coal industries





Technology Issues

Reliability: Gasification's "Achilles' Heel"

- **Reliability identified as the key technical challenge!!!**
  - Unable to meet performance milestones on which economics are based
  - Single train availabilities must be at least 90% for utility applications and greater than 97% for refineries and chemical complexes
  - EPCs unwilling/unable to guarantee integrated performance and risk huge liquidated damages
  - Must phase out multiple trains to improve economics
  - Standardize/modularize plants to optimize cost and provide schedule and performance guarantees

Key Gasifier Priorities

- **Issues**
  - Plant reliability due to excessive downtime from components
- **Needs:**
  - Feed injectors
    - Extend injector life from 2-6 months to >12 months
    - Elucidate factor contributing to injector failure
    - Multi-fuel injectors and variable orifice injectors
  - Refractory
    - Reduce material cost and extend life from 6-18 months to >3 years (or eliminate through new gasifier concepts)
  - Instrumentation
    - Temperature measurement – extend life beyond 30-45 days
    - On-line feed (fuel switching) and product analyses

Gasifier Technologies

- **Issues:**
  - Existing gasifier require economies of scale - amenable only to large-scale applications
  - Most not suitable for low-rank coals
- Needs:
  - Small-scale gasifiers for distributed generation market – hydrogen production
  - Eliminate need for refractory linings
  - Feedstock flexible – suitable for low-rank coals, high ash materials, biomass, etc.
  - Eliminate need for air separation plant

Feedstocks

- **Issues:**
  - Alternative feedstock availability – how much and at what cost?
  - Feedstock preparation – cost and impact on reliability and injectors
    - Difficulty injecting alternative materials into high-pressure gasifiers
  - Thermodynamic penalty for slurry feed systems
- **Needs:**
  - Reliable, continuous dry feed systems
  - Additives to increase coal concentration in slurries
  - Reliable flow measurement and on-line analytical instrumentation
  - Material development to prevent erosion/corrosion
  - New approaches to preparing and feeding low rank coals and alternative feeds, e.g., biomass
    - Removal of moisture to increase energy content
  - Feedstock characterization – impact on gasification performance

Gas Separation – Air Separation

- **Issues:**
  - Current ASU technologies primarily cryogenic
  - Oxygen production - 12-15% of capital cost of IGCC plants); consumes 10% of gross power production
  - Technologies operate at either very high or very low temperatures
- **Needs:**
  - New “step out” technologies that have lower capital costs and are more efficient
  - Ceramic-based membranes viewed favorably (high temperature operation, i.e., >850 ^{o}C) – but still high risk
  - Air extraction design for gas turbines a key issue
  - Intermediate temperature ASU may be desirable (50 to 350 ^{o}F)

Gas Separation – Hydrogen/CO_2

- **Issues:**
  - Sequestration/utilization technologies need to be proven; need storage options before removal is mandated
  - Most technologies provide either high pressure hydrogen or CO_2, not both
  - Technologies operate at either very high or very low temperatures
- **Needs:**
  - Preferred temperature of operation <800 ^{o}F
  - New “step out” technologies that have lower capital costs and are more efficient
  - Produce both high pressure hydrogen and CO_2

Synthesis Gas Cleanup

- **Issues:**
  - Industry has not invested in improving existing technologies or developing new concepts for >40 years
  - Existing technologies experience problems with or cannot remove certain trace contaminant in syngas, creating problems for turbines
  - Deep cleaning technologies are expensive and inefficient - only use when high-value products are produced
- **Needs:**
  - Deep cleaning technologies required to meet future environmental regulations (SO_x, NO_x, ammonia, HAPs, carbonyls, Hg, As, etc.)
  - Cost must be equal to or lower cost than conventional technologies
  - Improve reliability and performance of low-temperature chemical and physical solvent process; new low-temperature technologies
  - New technologies that operate closer to downstream process requirements, 300-700 ^{o}F (e.g., gas turbine, syngas conversion)

By-products

- **Issues:**
  - Disposition of ash/slag and sulfur will become an issue as more plants are deployed using high-sulfur feedstocks
  - Impact of alternative feeds on ash/slag quality/ marketability
- **Needs:**
  - Low-cost technologies to enhance ash/slag quality – beneficiation
  - Recovery of high-value trace metals from ash/slag
  - New market applications for ash/slag and sulfur
  - New environmental test methods for each market application to protect the public

Design Standardization/Modularization

- **Issues:**
  - Very large plants required for economics – difficult to finance
  - Each project designed from scratch – costly engineering
  - Plant start-up difficulties – time to capacity critical
  - Low plant reliability
- **Need:**
  - Standardized/modularized plant designs (phased construction)
  - Employ value engineering to reduce cost and footprint
  - Economic and efficient moderately sized plants
    - Size consistent with needs of utilities (market study required)
    - Can be mass produced and deployed on a modular basis
    - Start-up and reliability problems overcome by standard operation – increase customer confidence

Synthesis Gas Utilization

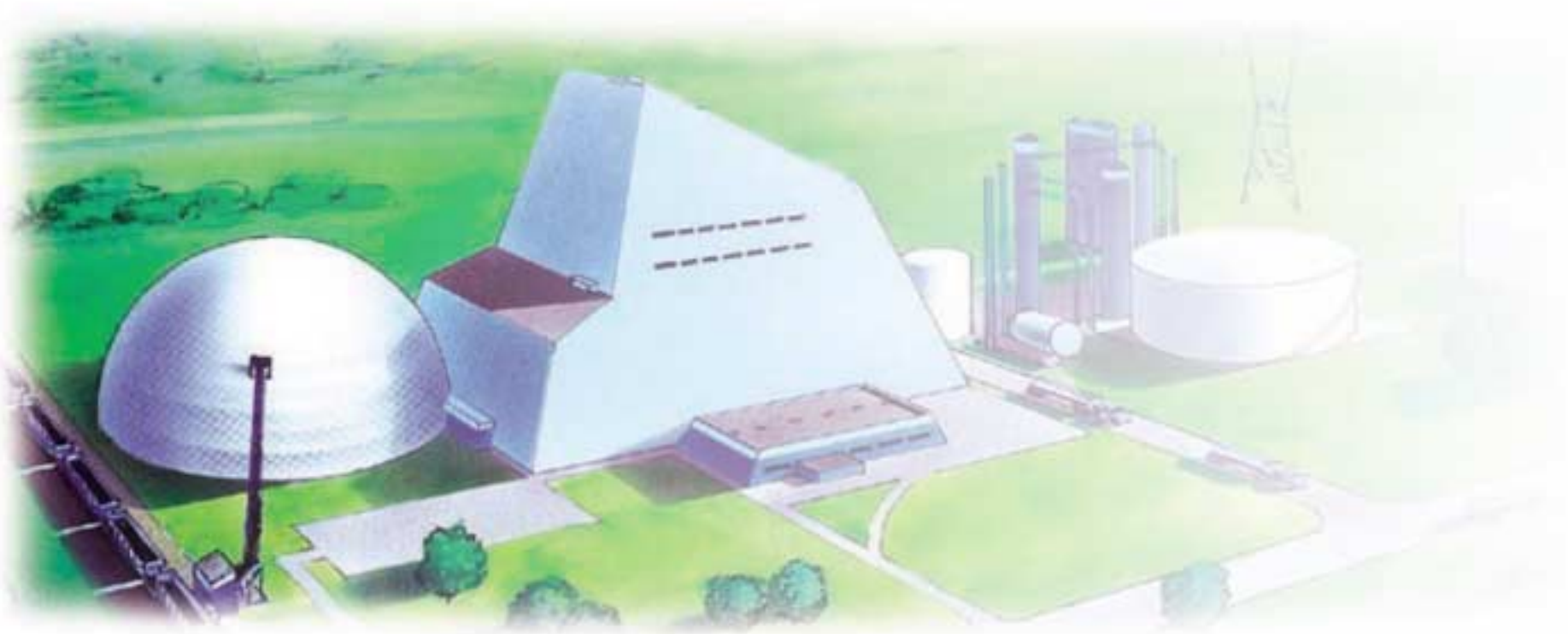
- **Issues:**
  - GT market driven by natural gas – concern about future availability and development of gas turbines
  - Uncertainties regarding impact of contaminants in the synthesis gas
- **Needs:**
  - Gas Turbines
    - Optimized development for synthesis gas combustion
    - Understanding of effect of impurities on GT performance (delamination, spalling embrittlement, and deterioration of thermal barrier coatings)
    - Low NO_x and/or catalytic combustors for synthesis gas
  - Fuel Cells
    - Drastic reduction in cost
    - Reduced levels of contaminants in synthesis gas

Informational Database

- **Issues:**
  - Repetition of mistakes – information not shared
  - Key performance milestones missed – liquidated damages
- **Needs: Informational Databases**
  - Industry-wide “Knowledge Management System”
    - Reliability statistics for existing plants
    - Component cost, availability, and reliability
  - Feedstock Performance
    - Chemical and physical properties of various feedstocks
    - Reactivity and gasification characteristics
  - Operation and Maintenance Problems
    - Address generic O&M problems common to the industry
    - e.g. “slurry handling design manual”

Instrumentation

- **Issues:**
  - Rapid, affordable, on-line instrumentation – key to further advancement of gasification
- **Needs:**
  - Affordable on-line analytical device to provide elemental composition of feedstock with time varying composition and other properties
  - On-line instrumentation to measure flow rates
  - Rapid on-line analysis of slag viscosity and instrumentation to measure slag thickness on the refractory
  - On-line instrumentation to tract refractory wear
  - On-line product gas analysis including trace components
  - Isokinetic particulate measurement, preferably in the gasifier



Where Do We Go From Here?

FY 2002 R&D Initiatives

- **Gasification Technologies Research Consortium**
  - Provide opportunities to identify and address key technology issues at the proof-of-principal level through novel ideas and creative approaches
  - Collaborative participation of multiple universities and not-for-profit research organizations
  - Industry management council provides direction

- **Gasifier Reliability/Performance Enhancements**
  - Materials development (i.e., refractory)
  - Improved feed injectors
  - Instrumentation (i.e., thermocouples, on-line analyzers, flow measurements, feed systems, etc.)

Clean Coal Power Initiative

- **Cooperative, cost-shared government/industry program**
  - Demonstrate emerging coal-based power generation technologies
  - Accelerate technology deployment to commercial use
  - Ensure coal technologies exceed “Clear Skies Initiatives” requirements
- **Ten year, $2 billion program – multiple solicitations**
- **Proposed project eligible as "CCT Demonstration Projects" for exemptions from NSR and NSPS**
- **First Round Solicitation**
  - Issued - 3/4/02
  - Proposals due - 8/1/02
  - Selections expected -1/8/03

Acknowledgements

- **James Childress, Executive Director, Gasification Technologies Council**
  - Obtaining support of GTC membership
  - Many helpful suggestions
  - Personal interest in the success of the process

- **Participating organizations**
  - Willingness to share thoughts with the DOE
  - Extensive preparation prior to meetings
  - Very productive meetings
  - Interest in results
  - Continued support of the gasification program

Visit The Gasification Technologies' Web Site at www.netl.doe.gov/coalpower/gasification