Advanced Coal Technology and Climate Policy Delegation to Europe October 5-14, 2007

Site Visits, Briefings, and Lessons Learned

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Outline of Presentation

- Delegation Background
- Site Visits to Integrated Gasification-Combined Cycle (IGCC) Power Plants
- Technology & Policy Briefings from Industry, Government & NGOs
- Lessons Learned

Delegation Overview

- Twenty-seven participants from 10 states: CA, DC, FL, IL, IN, MI, MS, OH, TX, WI
  - Industry executives
  - Governors staff, state agency heads, and state legislators
  - Representatives of environmental organizations and charitable foundations
- Funding from Edgerton and Joyce Foundations
- Staffing by Great Plains Institute, with assistance from Clean Air Task Force

Delegation Objectives

- Learn about large-scale commercial IGCC plants in Italy and visit Italian and Dutch facilities to assess operational experience.
- Understand European Union, UK and Norwegian policies and strategies to reduce greenhouse gas emissions
  - Focus on CO2 capture and geologic sequestration (CCS) and emissions trading
- Apply lessons learned in Europe back home in the U.S.

IGCC Site Visits: Italy

- ISAB Energy, Priolo, Sicily
  - 528 MW
  - GE gasifier technology
  - Fuel: high-sulfur and metal asphalt refinery by-product

ISAB Energy

- One of 4 commercial scale IGCC plants at Italian refineries
- Built in response to national 8-yr power purchase incentive
- Addressed ERG refinery's asphalt waste problem following EU sulfur limits in diesel fuel
- Over 90 percent availability achieved

IGCC Site Visit: The Netherlands

- Nuon Power, Buggenum, The Netherlands
  - 250 MW
  - Shell gasifier
  - Fuel: coal and biomass

Nuon Power Buggenum

- High availability achieved following plant modifications
- Biomass co-gasification with coal at 30%
  - Waste wood, dried sewage sludge and other biomass feedstocks (based on quality, supply and cost/tipping fees paid to Nuon)
- Nuon just awarded incentives from Dutch government to capture stream of CO2

Nuon's Magnum Project

- EUR 2 billion project based on Buggenum IGCC operational experience and future CO2 management needs
- 1,200 MW plant in final stages of permitting (750 IGCC-450 natural gas-combined cycle or NGCC)
  - 2011 start-up of NGCC
  - 2013 planned start-up of IGCC, pending design changes to reduce capital and construction costs
- Three-phased approach to CCS in North Sea reservoirs
  - Full CO2 capture for 250 MW in Phase I
- Capability for substantial biomass co-gasification planned

Brussels Briefing from EU Commission, Total and Alstom

- **EU Zero Emissions Platform: 10-12 projects with CCS by 2015 to enable adoption in all new plants by 2020**
  - **Further commercialization of IGCC (pre-combustion)**
  - **Initial commercial demonstration of other technologies: Oxyfuel (combustion in pure O2) & post-combustion capture (amine scrubbing, chilled ammonia, etc.)**

- **Multiple fossil energy feedstocks: coal, natural gas, and petroleum by-products**

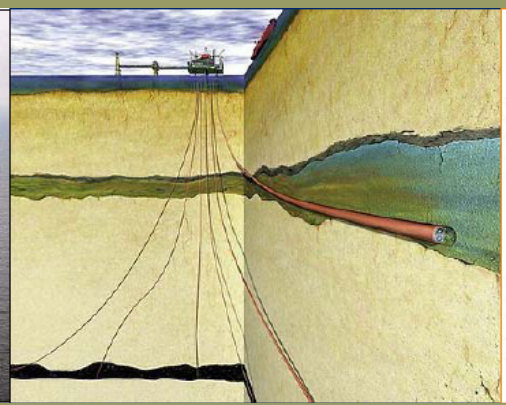
- **Incentives for projects and EU-wide development of CCS regulatory framework**

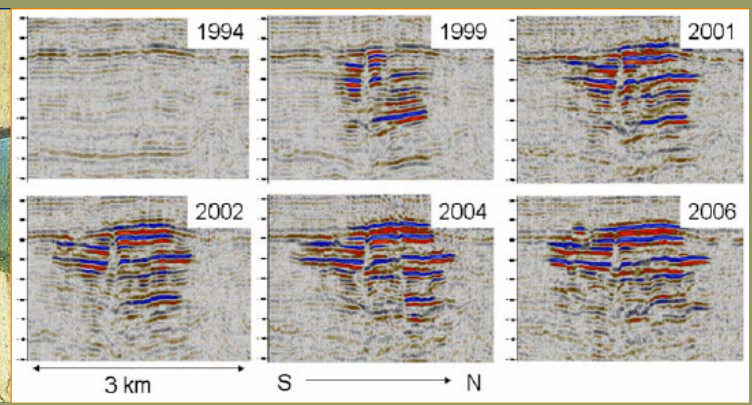
UK Briefing

- CCS critical to national commitment of 60 percent CO2 emissions reductions from 1990 levels by 2050
  - 60% of future energy, after renewables and nuclear, from fossil fuel in UK
- Development of national CCS framework consistent with EU
- National CCS competition: government to cover 100% of capture, transport and storage for power plant
  - Requirements: 300 MW or greater, 90% capture, operational by 2014 and sharing of intellectual property
  - Focus on accelerating demonstration of post-combustion capture as solution for existing conventional power plants
- UK Rationale for conventional coal:
  - US FutureGen will sequester CO^2 at IGCC

Norway Briefing

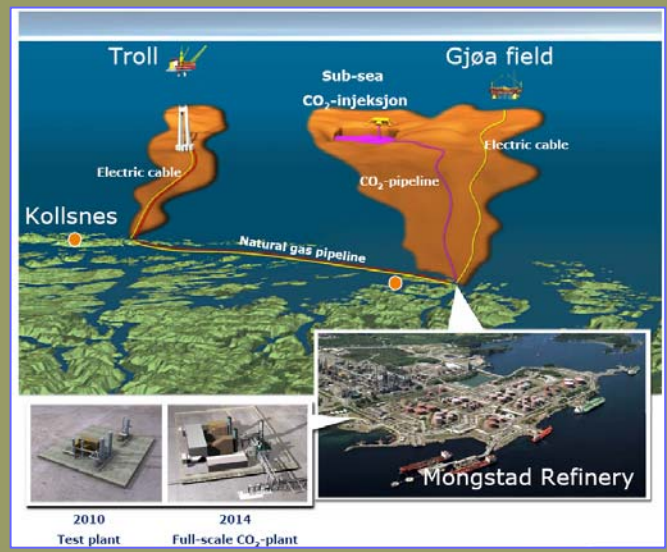
- National commitment: CO2-neutral economy by 2050
  - Past government fell over plans to build NGCC power plant without CCS (99% of electricity from hydro)
- CCS pioneer at Sleipner in North Sea: million tons of CO2 annually stripped from natural gas since 1996
- Early impetus for CCS from $45/ton CO2 tax on oil and gas industry in 1992
- North Sea Basin Task Force with UK to develop CCS regulatory framework and support deployment





Norway's Commercial CCS Projects

- Snøhvit started this year and will strip 0.7 million tons of CO2 annually from natural gas for injection into sandstone reservoir
- Mongstad Refinery will capture CO2 at NGCC plant: 100,000 tons in 2010 and 1.1 – 2.1 million tons annually by 2014
- Kårstø NGCC plant operational in 2007, with planned annual capture of million tons by 2011-12
- Proposed Halten project would demonstrate CO2 value chain, including using captured CO2 for enhanced oil recovery (EOR)



Royal Dutch Shell Briefing

- Coal to dominate future global energy supply & largest segment of growth
- Steady improvement in Shell's gasifier performance, including with biomass
- 15 projects in China, 5 operational: syngas, liquids & chemicals
- IGCC in Europe and US: rising project costs and uncertainty over future CO2 requirements present barriers
- Shell's response:
  - Greater equity investment role
  - 10-fold increase in R&D: reduce capital cost, improve performance & expand feedstock flexibility

E.On Briefing

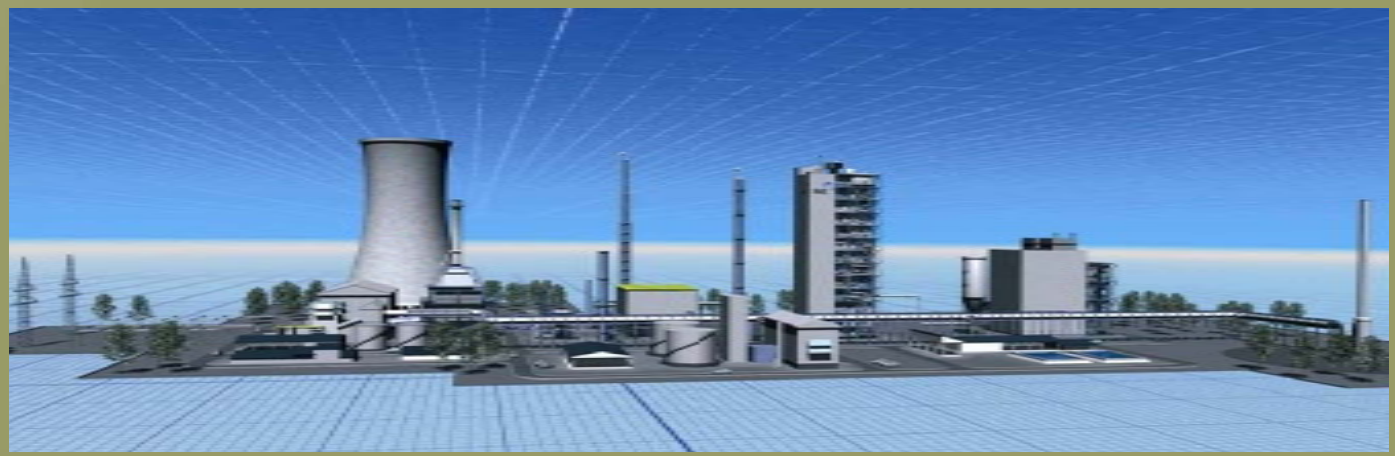
- Major European power company pursuing post-combustion capture and IGCC pathways as part of EUR 60 billion in investments by 2010

- 1600 MW Kingsnorth supercritical combustion units by 2012-13 to replace older coal plant
  - CO2 capture ready: actual capture potentially accelerated in response to UK government competition

- 360 MW Killingholme IGCC project with CCS in southern North Sea
  - 2012-13 start date now in doubt due to UK government announcement

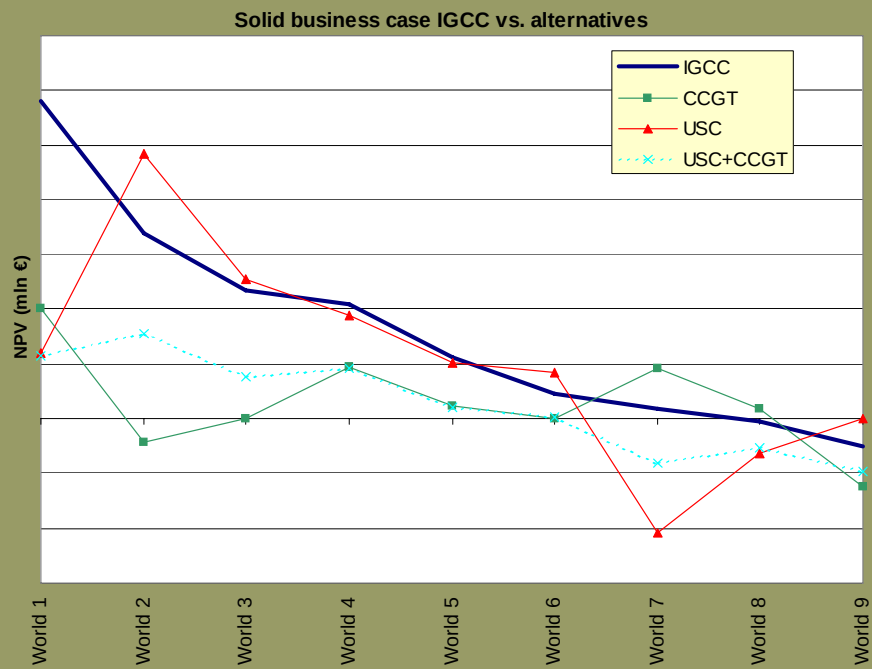
RWE Briefing

- **Large diversified energy company with operations in UK and continental Europe**
- **Corporate CCS plan**
  - **2400 MW post-combustion capture plant for UK**
  - **450 MW lignite IGCC with CCS by 2014 for Germany**
  - **Operational CO2 storage and pipelines by 2014**



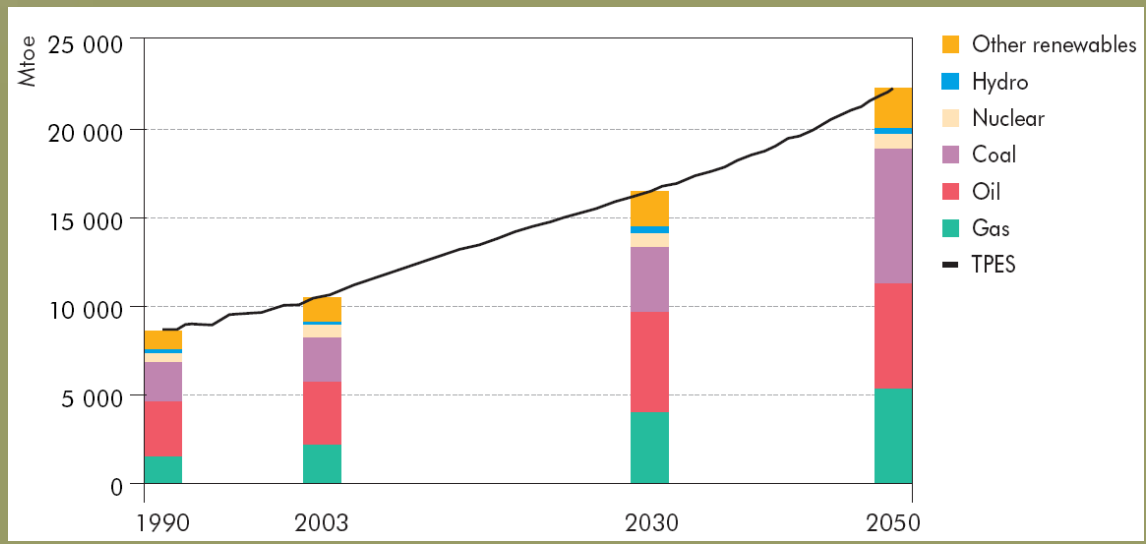
Delegation Lessons Learned

- **IGCC is commercially demonstrated in Europe.**
  - European experience confirms reliability of gasification technologies for electric power.
  - Availability of large IGCCs using refinery feedstocks exceeds 90 percent.
  - European companies with operational IGCC experience are pursuing capacity expansions and new IGCC projects.



European Consensus on CCS

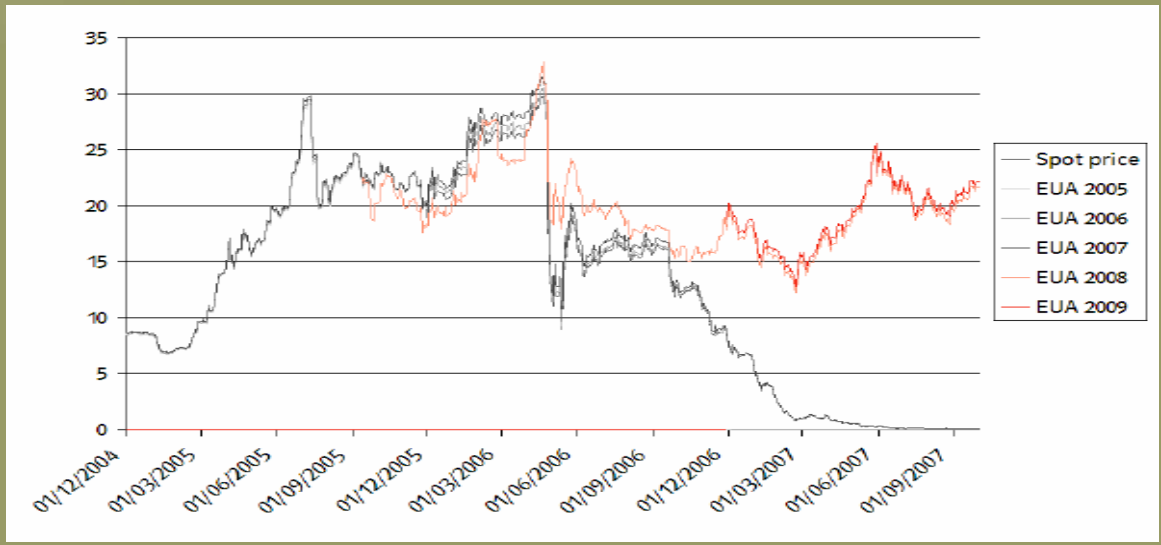
- **Europe has reached consensus that CCS from coal and other fossil fuels must be a fundamental component of its energy system and portfolio of CO2 reduction options.**
  - **Coal will remain a dominant source of future electric power production in Europe, despite energy efficiency and renewable energy gains that far exceed those of the U.S. to date.**
  - **Commercial IGCC experience and large-scale North Sea CCS demonstrations provide the confidence to commit to deployment.**



IEA: *Energy Technology Perspectives 2006 – Scenarios & Strategies to 2050*

Better Market Signals and Regulatory Certainty Needed

- **Despite Kyoto and CO2 emissions trading, Europe lacks effective and sufficient market price signals for CO2 and long-term regulatory certainty for major investments in advanced coal generation and CCS.**
  - **European Trading Scheme has had significant volatility in price of CO2 during Phase 1 start-up.**
  - **Uncertainty looms over post-Kyoto CO2 regulation after 2012.**
  - **Regulatory/liability framework for CCS still under development.**



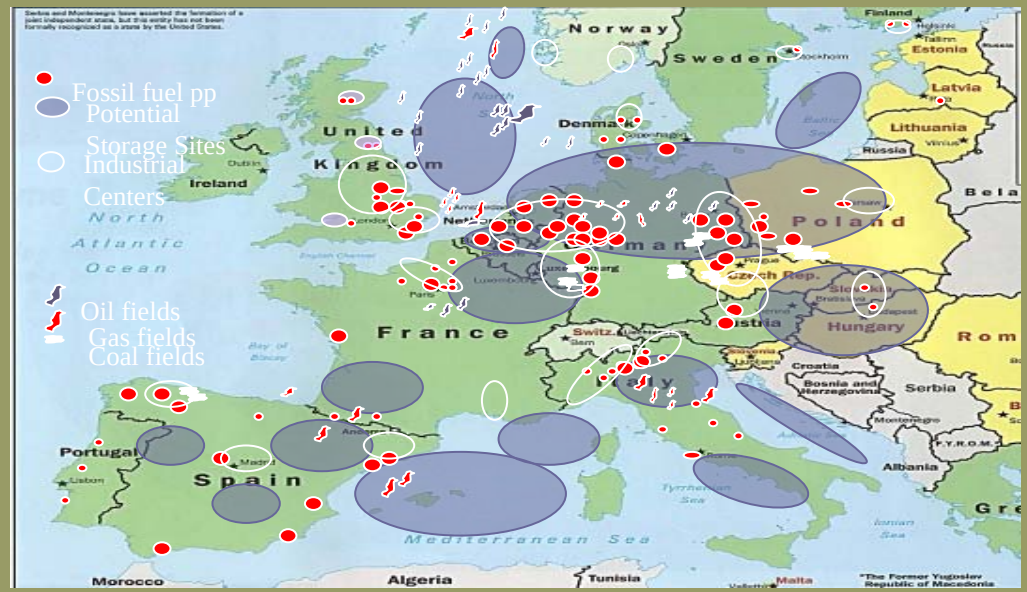
Sustained Incentives Yield Commercial Deployment

- **Where policy in Europe provides sustained incentives, progress toward commercial demonstration and deployment of IGCC and CCS projects has been achieved.**
  - **8-year national power purchase incentive allowed development of Italian refinery IGCCs.**
  - **Combination of EU and Dutch national financial incentives provided for biomass co-gasification with coal at Nuon IGCC plant.**
  - **Norwegian CO2 tax of $45/ton on oil and gas industry prompted moves toward CCS.**

Further Public Support Needed

Deployment of IGCC with CCS and early demonstration of post-combustion capture technologies needs ongoing regulatory & government financial support.

- **Capital/construction costs of IGCC and other projects in Europe have increased.**
- **Oxyfuel and post-combustion technologies have not yet been commercially demonstrated.**
- **Highly-efficient conventional coal plants, with purchase of CO2 allowances, remains the low-cost option short-term.**



Biomass Co-Gasification Potential CO2 Management Option

Biomass co-gasification with coal is commercially demonstrated in Europe.

- Nuon has demonstrated reliability of biomass co-gasification at scale, but postponed commercial expansion pending further incentives.

- Potential CO2-negative energy production through co-gasification of biomass with CCS will require additional incentives to reflect CO2 benefits.

U.S. Still Has Opportunity to Lead

With the right policy and regulatory framework in place, the U.S. can lead commercialization of advanced coal and CCS.

- Several IGCC and other advanced coal plants nearing regulatory approval
- CCS through EOR occurs at larger scale in U.S. than Europe (e.g. 3 million tons annually at Dakota Gasification in ND).
- Millions of tons of CO2 managed for EOR in Texas' Permian Basin.

Map of CO2 Fields in the United States
(Source: Enhanced Oil Resources, Inc)

Thank You

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- Support for the delegation from the Edgerton and Joyce Foundations is gratefully acknowledged.
- For more information on the delegation, please see www.gpisd.net