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Oregon

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January 29, 2008

MEMORANDUM

TO: Council Members

FROM: Terry Morlan

SUBJECT: Presentation on Carbon Sequestration

Most analyses of what would be required to meet proposed carbon dioxide emission goals include carbon sequestration in some form. Melinda Eden asked for a presentation to educate the Council about carbon sequestration. This is intended as important background information for the Sixth Power Plan.

Dr. Mark Trexler, of Trexler Climate + Energy Services, will discuss sequestration with the Council. He has been asked to provide an overview of various sequestration technologies, both biological and geological. Mark Trexler is a well known expert in this area and can place sequestration in the broader context of energy planning.

I have attached a biography for Dr. Trexler and a description of his company's capabilities.

Attachments

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TC+ES

TREXLER CLIMATE + ENERGY SERVICES

THE NATURAL RESOURCE FOR
CLIMATE CHANGE MITIGATION SERVICES

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**Management:**Management
Overview**Dr. Mark C. Trexler,**
PresidentLaura H. Kosloff,
Senior Vice President
and General CounselJames F. Pienovi,
Strategic Planning and
Market Development**Related Links:****For more
information about
a staff member,
click on his or her
name at left****See also:**

- TC+ES Milestones

- TC+ES Firsts

Dr. Mark C. Trexler, Managing Director
<mailto:mtrexler@climateservices.com>

Dr. Mark C. Trexler is Managing Director of EcoSecurities Global Consulting Services. Mark has spent the last 17 years working on climate change issues, and founded TC+ES in 1991. He is involved in corporate strategic planning for climate change mandates and in the development and implementation of corporate response strategies, and his company was a leader in development of the international greenhouse gas market including the design and funding of carbon offset projects around the world.

Dr. Trexler has published extensively on technical and policy issues related to climate change mitigation and has served as a lead author for the Intergovernmental Panel on Climate Change. He is a member of the editorial board of *Mitigation and Adaptation Strategies*, a leading climate journal. Under his direction, TC+ES can claim a number of "firsts" in the climate change mitigation field, including writing the first carbon offset contracts in the field and providing litigation assistance and expert testimony in the first successful carbon offset contested regulatory proceeding in the United States. Prior to establishing TC+ES, Mark worked at the World Resources Institute in Washington, DC, where he managed technical analysis of the very first carbon mitigation projects pursued by U.S. companies. Mark also has worked extensively on energy policy issues such as power-plant siting, technology R&D policy, and efficiency standards.

Dr. Trexler earned his M.P.P. in 1982 and his PhD in 1990 from the Graduate School of Public Policy at the University of California, Berkeley, and his B.A. in 1978 from Antioch College in Yellow Springs, Ohio. He speaks German, Italian, French, and Spanish.

> \\fs2\power\TM\Council Mtgs\2008\Feb 08\Trexler Bio

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**Company
Overview:****Related Links:****Introduction****Introduction**

- TC+ES Firsts

Corporate
Responsibility

- TC+ES Milestones

TC+ES Capabilities

Trexler Climate + Energy Services, Inc. (TC+ES) is an internationally recognized leader in the emerging field of climate change risk management, with more than 13 years of demonstrated experience in areas including:

- Corporate risk assessment and strategic planning in the area of climate change

- The development of the Cli-Mit toolbox of decision support tools for corporate clients

- Helping clients explore the opportunities for competitive advantage through their climate strategies

- Understanding and forecasting the behavior of the greenhouse gas market

- Identifying mitigation opportunities and evaluating and developing carbon offset projects

- Tackling the toughest policy challenges in this field, including the design of early action crediting systems, and determining how additionality should be approached at the project level

TC+ES is one of just a few companies worldwide specializing in climate change mitigation policies, technologies, and projects, and we've been doing it longer and (according to our clients) better than anyone else. TC+ES has always specialized in the provision of services to the private sector, although it has also supported the work of leading NGOs like the Nature Conservancy and the Solar Electric Light Company, and of domestic and international agencies including the Global Environment Facility and the United Nations Development Programme.

TC+ES's wide range of products and services are tailored to the unique needs of our clients. As a specialized firm with more than a decade of experience in this field working with companies large and small, TC+ES has amassed an unparalleled amount of insight into how corporate strategies can most credibly and cost-effectively position companies for an uncertain future.

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CCS and Power Planning – Chicken and Egg Dilemmas

Dr. Mark C. Trexler
Managing Director, EcoSecurities Global Consulting
Services Group

Portland, Oregon 2/12/2008

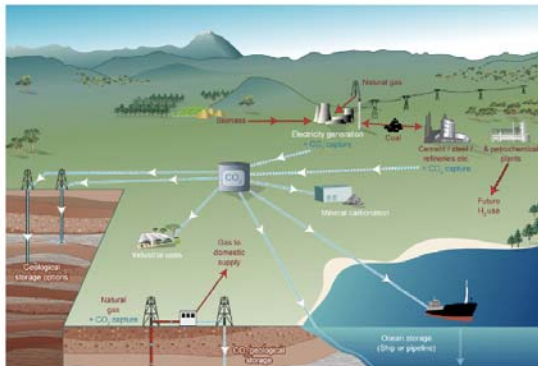
Table of Contents

1. Setting the CCS Stage
2. The GHG Market Context
3. What's The Role for CCS?

Table of Contents

1. Setting the CCS Stage

Introduction



Carbon Capture and Sequestration refers to a suite of technologies that capture CO₂ from waste gases produced by industrial processes, and dispose of the CO₂ in a permanent fashion

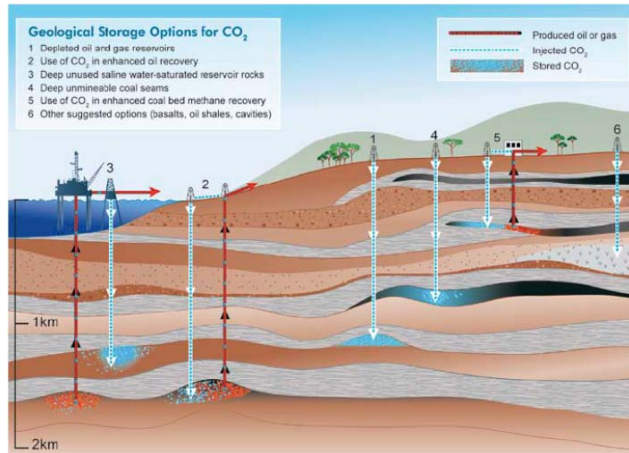
Carbon Sequestration: Overview

- > Geologic Sequestration
 - Stores CO₂ in geological formations below the surface of the earth
 - Only currently viable process
- > Ocean Sequestration
 - Stores CO₂ by pumping deep into the ocean
 - Feasible but hampered by political considerations
 - Sequestration in carbonate formations beneath the sea-floor may work
- > Mineral Sequestration
 - Disposes of CO₂ by forming solids CaCO₃ or MgCO₃
 - Offers promise of 'hassle free' sequestration
 - Still in research phase

Technologies

- > Carbon Capture
 - Separate CO₂ out from other gases in the waste stream of a power plant and concentrate it into a pure stream of CO₂.
 - Fossil fuels are combusted in air. As a result, the CO₂ that comes out of the flue gas is dilute (5-15%). Disposal technologies require a relatively pure stream of CO₂ (>95%)
 - The primary cost driver of CCS
- > Carbon Transportation
 - CO₂ is compressed to >100 atm (2,000 psi)
 - CO₂ is transported through pipelines
- > Carbon Sequestration
 - Take a pure stream of CO₂ and dispose of it in a hopefully permanent means in aquifers, geological formations, or other reservoirs

Carbon Sequestration: Geologic



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Costs: Capture

Capture Technology	Cost Range (US\$/tonne CO ₂ avoided)
Natural Gas Combined Cycle Plant	37-74
Pulverized Coal Plant	29-51
Integrated (coal) Gasification Combined Cycle Plant	13-37

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Costs: Transportation

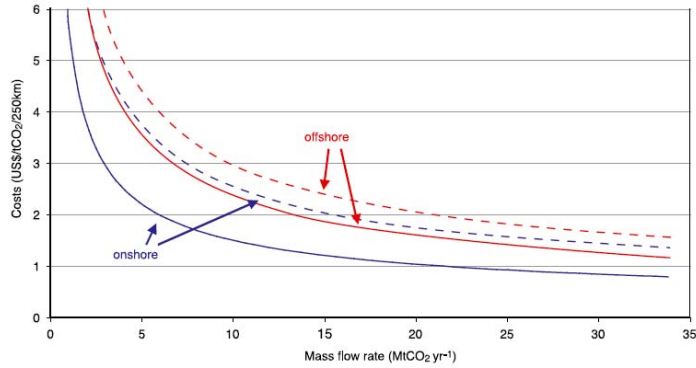


Figure 8.1 CO₂ transport costs range for onshore and offshore pipelines per 250 km, 'normal' terrain conditions. The figure shows low (solid lines) and high ranges (dotted lines). Data based on various sources (for details see Chapter 4).

Costs: Storage

Storage Option	Cost Range (US\$/tonne CO ₂ stored)
Geological	
-Storage	.5-8
-Monitoring	.1-.3
Ocean	
-Pipeline	6-31
-Ship	12-16
Mineral Carbonation	50-100

Costs: Total

Power Technology	Cost Range (US\$/tonne CO ₂ Avoided)
Pulverized Coal	30-70
Natural Gas Combined Cycle	38-91
Integrated (coal) Gasification Combined Cycle	14-53

Table of Contents

2. The GHG Market Context

The Role of GHG Markets

- > CCS Could Be Pursued Through Purely CCS Mandates
- > But Likely to Occur Within the Context of GHG Markets
 - A much more efficient approach to incentivizing cost-effective mitigation options
- > But Makes the Decision to Invest in CCS a Much More Difficult One
 - Will CCS be cost-effective?
 - Does it justify development costs?
 - Does it justify permitting costs?
 - Does it justify capital costs?
 - Does it justify insurance costs?

Examples of GHG Price Anticipation

- > A Wide Variety of “Price Signals”
 - Chicago Climate Exchange: <\$3/ton
 - Current CER Prices: \$10-20
 - EU ETS Price Peak in 2005: \$45
 - Forecasted EU ETS Prices: \$20-35
 - Voluntary Environmental Branding: \$5-10
 - 550 ppm Stabilization Modeling: \$75-100

2010 GHG MAC Curve

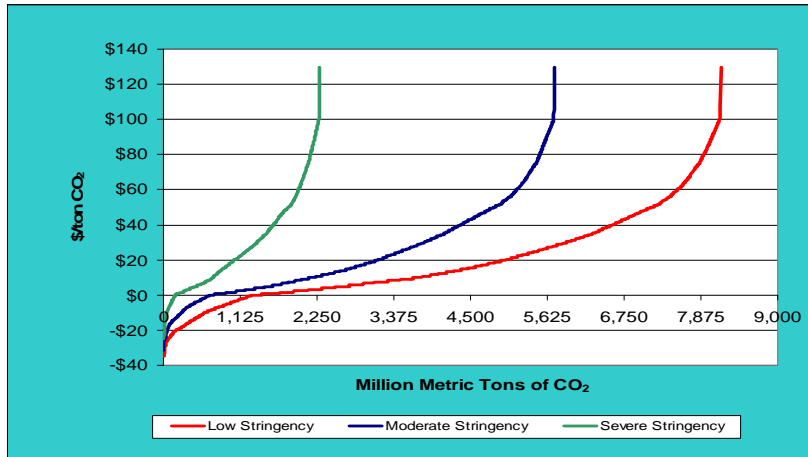


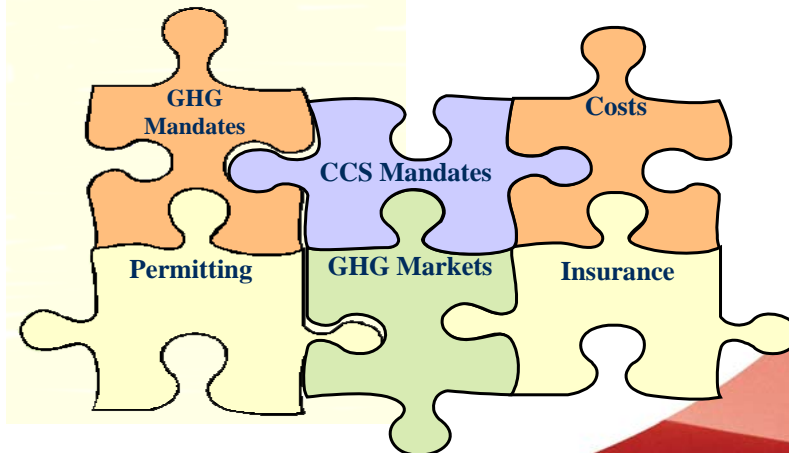
Table of Contents

3. What's the Role for CCS?

How to Think About CCS

- > A Key Factor in GHG Market Demand?
 - Are we assuming simple CCS mandates?
- > A Key Factor in GHG Market Supply?
 - Are we assuming CCS is part of the larger supply curve, and will compete in those markets?
- > Is CCS Susceptible to GHG Market Uncertainties?
 - Timing, risks, capital commitments?
- > Is CCS Competing With Other “Disruptive” Mitigation Technologies
 - Technologies like ocean fertilization?

Will The Pieces Fall Into Place for CCS?



Portraying CCS as a Key Option

- > The Technical Potential of CCS is Clearly Huge
- > But in What Context is CCS Being Viewed?
 - Based on current market value of EOR CO2 (\$15/ton)?
 - Based on simple cost of injection of almost pure CO2 (\$8-10/ton)?
 - Based on current costs of capture through storage?
 - Pulverized coal: \$30-70/ton
 - Gasified coal: \$15-55/ton
 - Natural gas: \$40-90/ton
- > Do the Economics and Characteristics of CCS Fit Into Policy and Market Forecasts, and Realities of Financial Decisionmaking?

For More Information

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