



ZECA Corporation

Great Plains

Coal Gasification Plant

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production
Concepts

Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

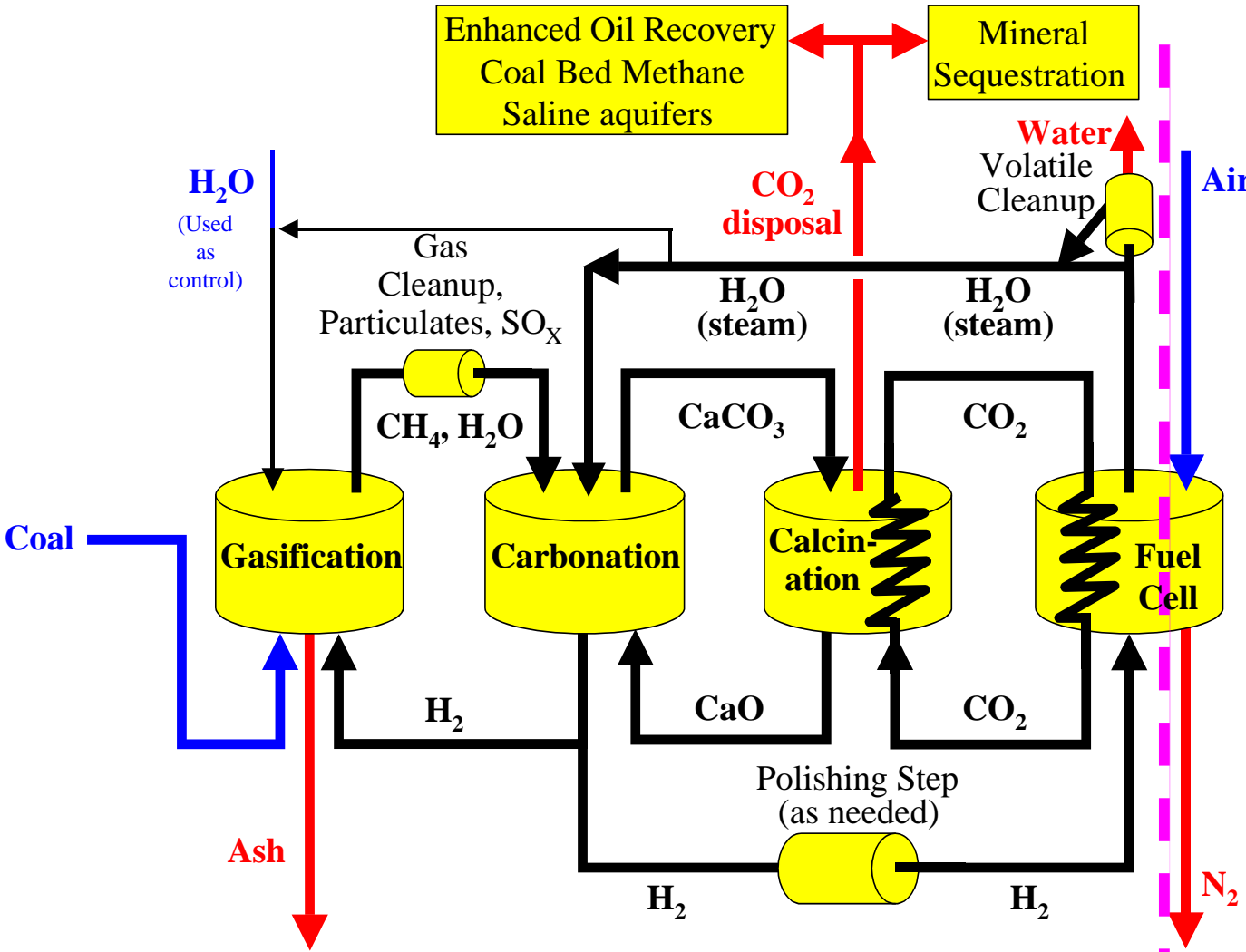
ZEC Potential – Why the technology is so interesting.

600 MWe
 Conceptual
 Power Plant
 with High
 Temperature
 Fuel Cells

<i>Items</i>	<i>Base Case</i>
Efficiency, HHV %	68.9
Total Plant Cost, \$/kWe	1,518
Cost of Electricity (COE), \$/kWh	0.0432
Tons of CO₂ Sequestered per Year per MWe	4,090
COE, \$/kWh with Sequestration at \$20/ton of CO₂	0.054

Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

ZEC Power Generation Concept



Stanford April 2004

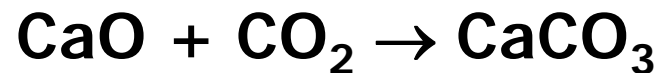
Hydrogasification



H₂ Production, CO₂ removal



Reforming Energy from



Power Production



Pure CO₂ regeneration



The Hydrogen Screening Study

Concept 1, the ZECA hydrogasification process is used to produce a synthesis gas, hydrogen and CO₂ from the oil sand coke in the presence of calcium oxide (lime).

Concept 2, a partial oxidation gasification process (Texaco, Shell, or Global Energy types) is used to produce the synthesis gas. The synthesis gas is then chemically shifted to form H₂ and CO₂. The gas treatment and hydrogen separation are conventional commercial technologies.

Concept 3, the ZECA hydrogasification process is used to produce a methane-rich synthesis gas, which is converted to hydrogen via commercial steam reforming techniques.

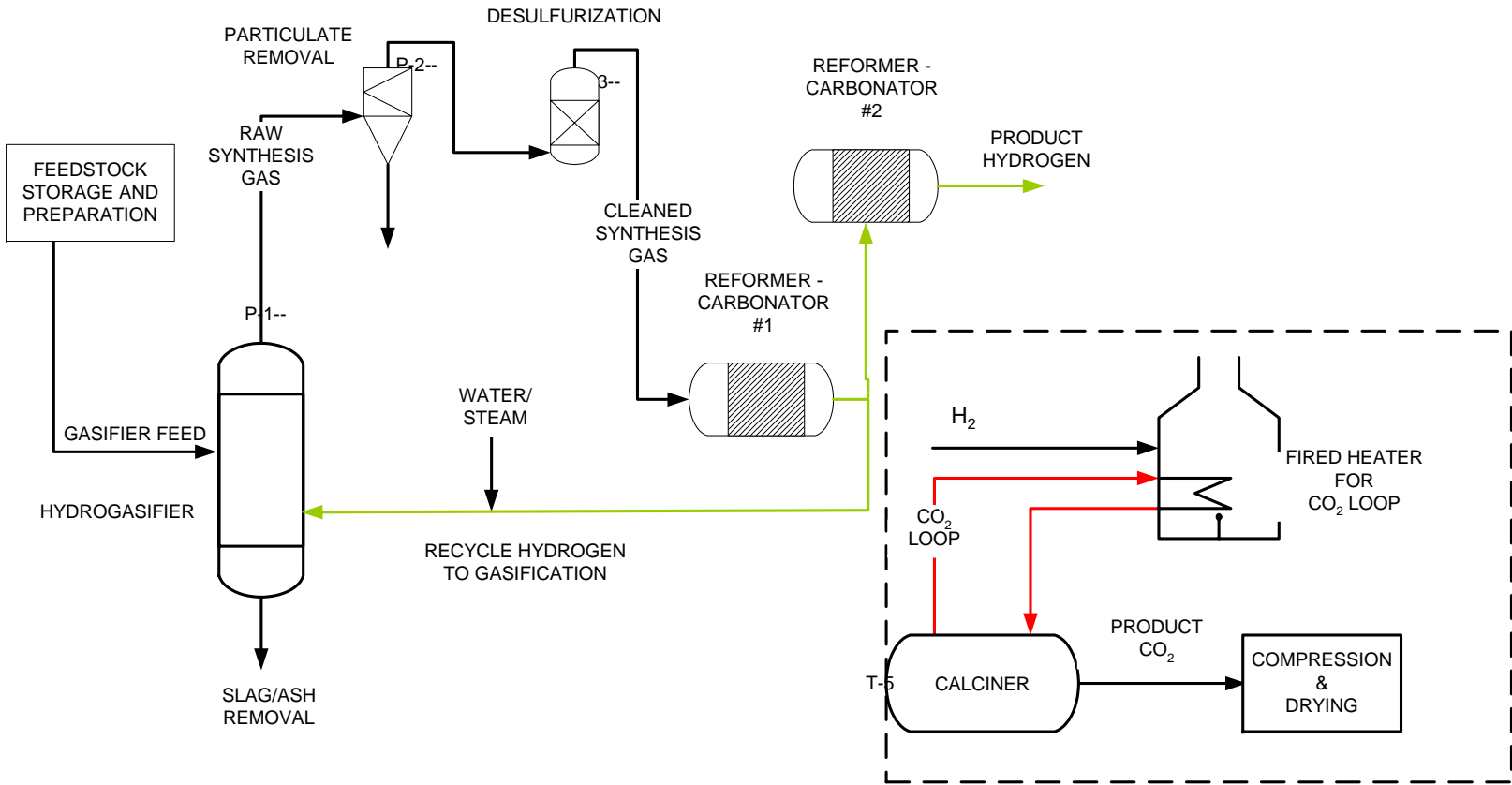
Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

Summary of Results

- ZEC Technology Hydrogen Costs About 30% Less Than For Traditional Gasification With Hydrogen Production. Both Concepts Include CO₂ Separation.
- ZEC Technology is Competitive With Traditional Steam Methane Reforming at a Natural Gas Feed Price of US\$4.50 per MMBtu or Less.
- ZEC Technology is Less Mature Than Traditional Gasification and Requires Significant Test and Development. Neither Version Has Been Demonstrated for CO₂ removal and Hydrogen Production.

Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

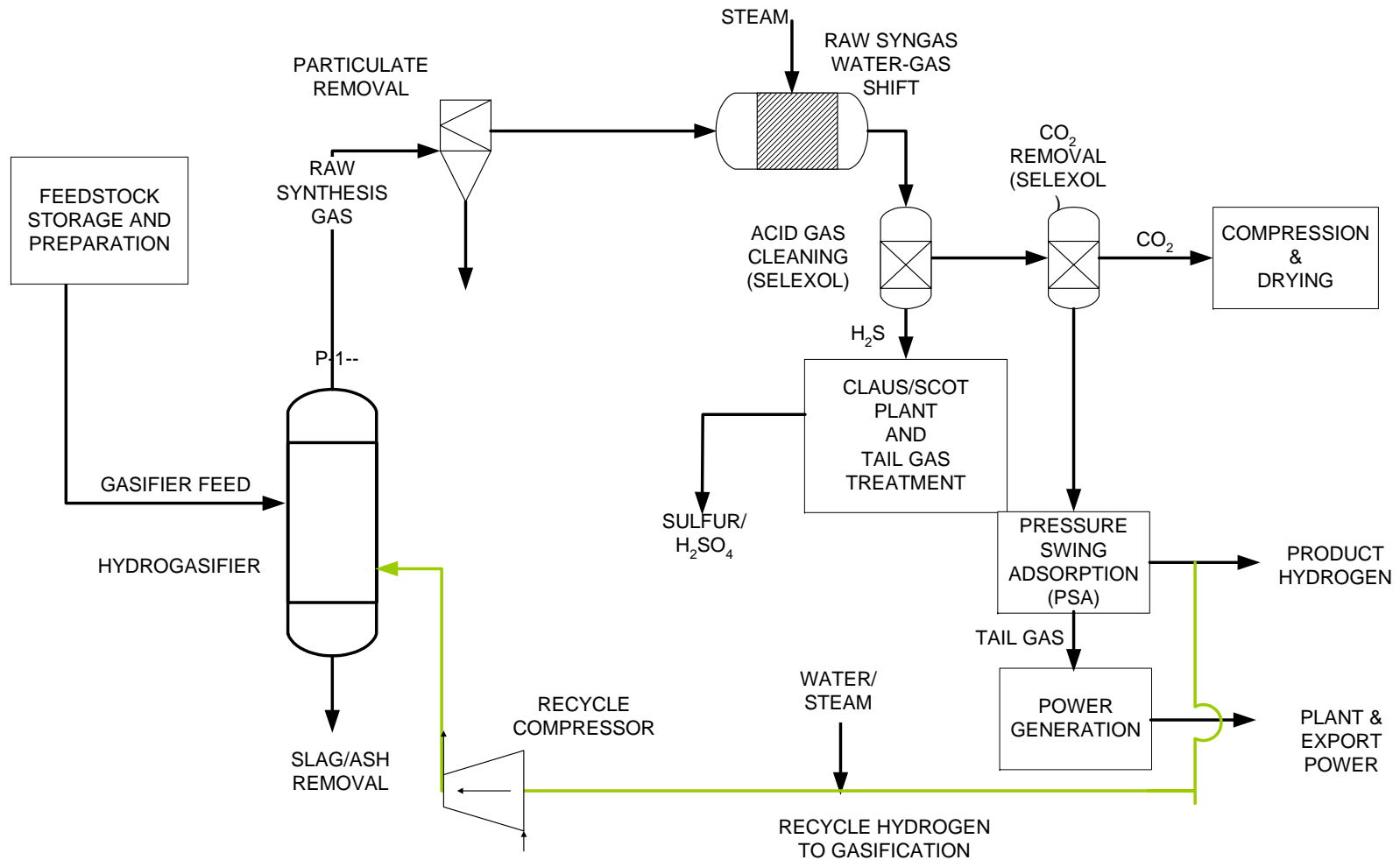
Concept 1, ZEC Hydrogen Production with Lime CO₂ Capture



Stanford April 2004

Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

Concept 3, Hydrogasification With Water-Gas Shift



Stanford April 2004

**Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts**

Concept Criteria

<i>ITEMS</i>	<i>ZEC Hydrogen Production, Concept 1</i>	<i>Partial Oxidation Gasification, Concept 2</i>	<i>Hydrogasification with Water-Gas Shift, Concept 3</i>
Hydrogen Production, TPD	418	418	418
Hydrogen Production, MMSCF/D	150	150	150
Coke Input, T/D	2,821	2,500	2,500
Operating Capacity	0.9	0.9	0.9

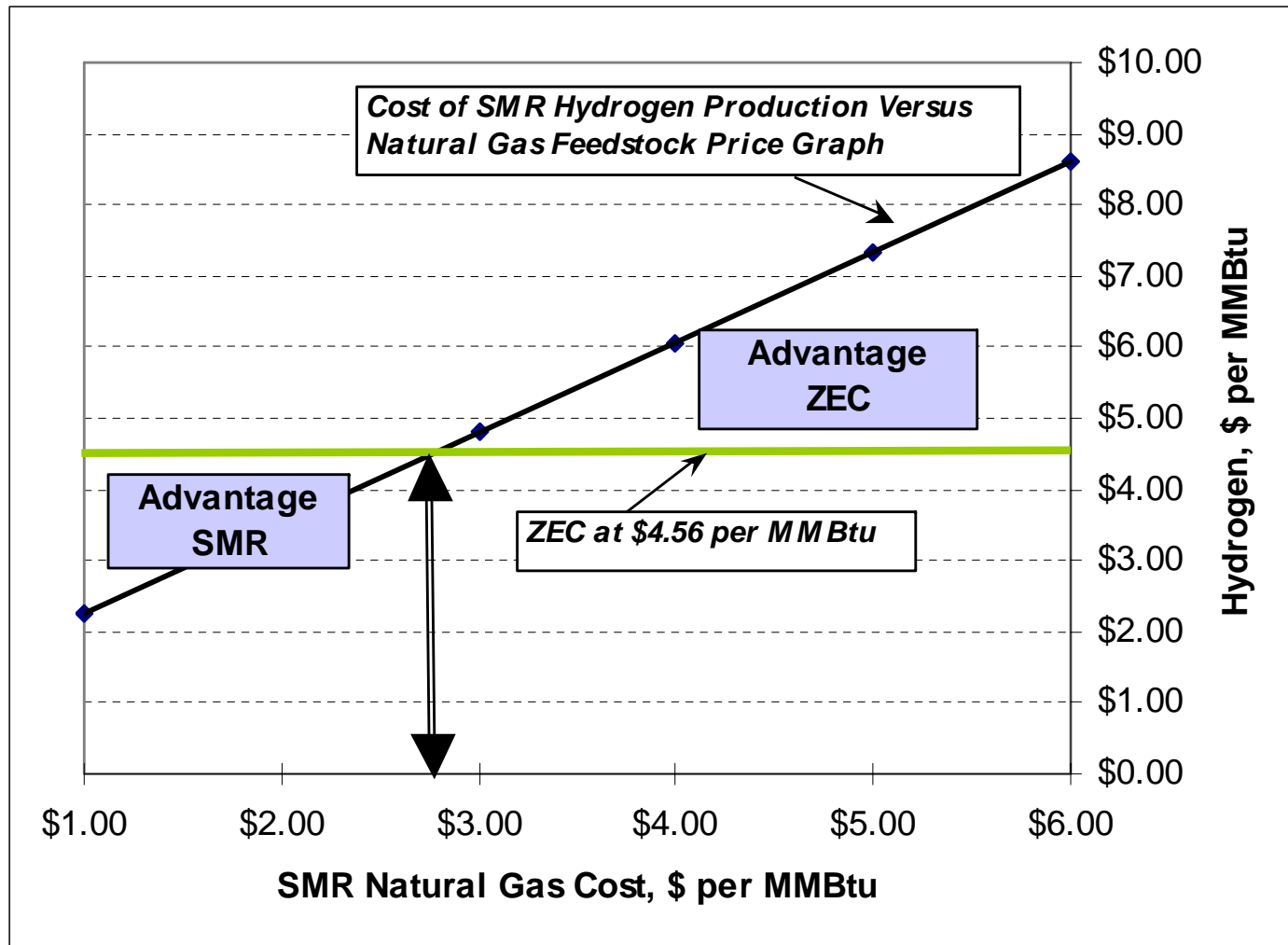
Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

Summary of Economic Results

<i>Economic/Financial Conditions</i>	<i>Cost of Hydrogen, \$ per MMBtu</i>		
	<i>ZEC Hydrogen Production, Concept 1</i>	<i>Partial Oxidation Gasification, Concept 2</i>	<i>Hydrogasification with Water-Gas Shift, Concept 3</i>
<ul style="list-style-type: none"> • Cost of Money = 11% • Investment Duration = 15 years • Cost of Coke = \$5 per ton 	\$ 4.56	\$ 5.81	\$ 4.54
Comparative Cost Ratio	0.78	1.00	0.78
<ul style="list-style-type: none"> • Cost of Money = 11% • Investment Duration = 15 years • Cost of Coke = \$0 per ton 	\$ 4.28	\$ 5.57	\$ 4.29
Comparative Cost Ratio	0.77	1.00	0.77

Zero Emission Carbon (ZEC)
Hydrogen and Carbon Dioxide Production Concepts

Comparison of ZEC and SMR Hydrogen Costs



Stanford April 2004

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

Future Tests, Development and Engineering

▪ **Hydrogasification**

- ✓ Reactivity and Carbon Utilization
- ✓ Methanation
- ✓ Heat and Material Balance

▪ **Reforming and Carbonation**

- ✓ Catalyst Requirements, Availability or Development
- ✓ Reforming Reactions with Coke, Water and Limestone
- ✓ Carbonation Under ZEC Environment

▪ **Calcination Operation**

- ✓ Heat Transfer Issues
- ✓ Limestone Makeup Requirements



Wabash River IGCC Repowering

▪ **Process Design Systems Integration**

- ✓ Hydrogen Recycle and Water/Steam
- ✓ Thermal Energy Source for Calcining
- ✓ Synthesis Gas Cleaning (Hg, S, ?) and Product Gases Treatment
- ✓ Power Generation/Compression Work
- ✓ High Temperature Materials Handling, and other HT Issues

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

Future Tests and Development

- **Hydrogasification**
- **Reforming and Carbonation**
- **Calcination Operations**

- Laboratory Tests and Equipment Designs
- Modification of Existing Equipment
- Pilot Bench Scale Tests

OBJECTIVES

1. Design Data Specific to Oil Sand
Coke, Bitumen, Ores
2. Data for Scale-up to Larger Pilot
Plant



1,800 MTPD Air Separation Plant

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

Engineering and Design

- **Hydrogasification**
- **Reforming and Carbonation**
- **Calcination Operations**

- Coordinate Lab Work and Design Requirements
- Integrate Lab Results With Oil Sands Hydrogen Designs, Costs, and Economics
- Communications and Data Collection Re Catalyst and Equipment Suppliers

OBJECTIVES

1. Engineering and Cost for Pilot Plant
2. Engineering Design, Costs and Economics for Commercial Plant



DOE Power Systems Development Facility, Wilsonville

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

Other Zero Carbon Information

Zero Emission Coal Technologies, A Prudent Man Approach to North American Energy Security by John Ruby, Alan Johnson, Dr. Hans Ziock, Dr. Klaus Lackner, the 27th International Technical Conference on Coal Utilization and Fuel Systems, March 2002.

Technical Progress in the Development of Zero Emission Coal Technologies, H.J. Ziock, E.L. Brosha, F.H. Garzon, G.D. Guthrie, R. Mukundan, T.W. Robison. B. Roop, B.F. Smith, A.A. Johnson, K.S. Lackner, A. Kramer, F. Lau, E.J. Anthony, J. Wang, J. Ruby, the 20th Annual International Pittsburgh Coal Conference, September 2002.

Zero Emission Coal Alliance Project Conceptual Design and Economics, John Ruby, Mohammad Nawaz, the 26th International Technical Conference on Coal Utilization and Fuel Systems, March 2001.

Zero Emission Coal, A New Approach And Why It Is Needed, by Hans-Joachim Ziock, Los Alamos National Laboratory, Los Alamos, NM 87545; et al, Eighteenth Annual International Pittsburgh Coal Conference December 4-7 2001 Newcastle, New South Wales, Australia.

Zero Emission Coal, by Hans-Joachim Ziock and Klaus S. Lackner, Los Alamos National Laboratory, Los Alamos, NM 87545; 5th International Conference on Greenhouse Gas Technologies, Cairns, Australia, August 14-18, 2000.

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

Other Zero Carbon Information

Anaerobic Hydrogen Production, Precursor to Zero Emission Coal, LA-UR-00-1850, Hans-J. Ziock, Klaus S. Lackner, Douglas P. Harrison.

Variations on Zero Emission Carbon, Alan A. Johnson and Hans-Joachim Ziock.

Sulfur Tolerant Anodes for SOFCs, Rangachary Mukundan, Eric L. Brosha, and Fernando H. Garzon Los Alamos National Laboratory, Materials Science and Technology Division, Los Alamos, New Mexico 87545 *Electrochemical and Solid-State Letters*, 7 (1) A5-A7, 2004.

The work of the project and ZECA Corporation was recognized in the December 2003 issue of *Scientific American* magazine as the Business Leader in Environment. The work was chosen as one of the SCIENTIFIC AMERICAN 50, which "recognizes the singular accomplishments of those who have contributed to the advancement and technology in the realms of science, engineering, commerce and public policy."

For additional information please visit the ZECA, Los Alamos National Laboratory, Columbia University and Nexant web sites:

<http://www.zeca.org/>

http://www.lanl.gov/energy/est/zeca/ZECA_Factsheet.pdf

www.nexant.com/services/AdvancedTech/clean-fossil/zero.html

<http://www.seas.columbia.edu/earth/EECEnergy.html>

Zero Emission Carbon (ZEC)

Hydrogen and Carbon Dioxide Production Concepts

QUESTIONS, DISCUSSION; The Path Forward

