Models for Environmentally Sound and Economically Viable Carbon Dioxide Sequestration Opportunities

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Where Energy Comes From

It is the genius of a people that determines how much energy is produced; the presence of energy in the earth is not enough. …..

energy must be sought first of all in our minds.

Wallace Pratt, 1934

energy substituted for "oil"

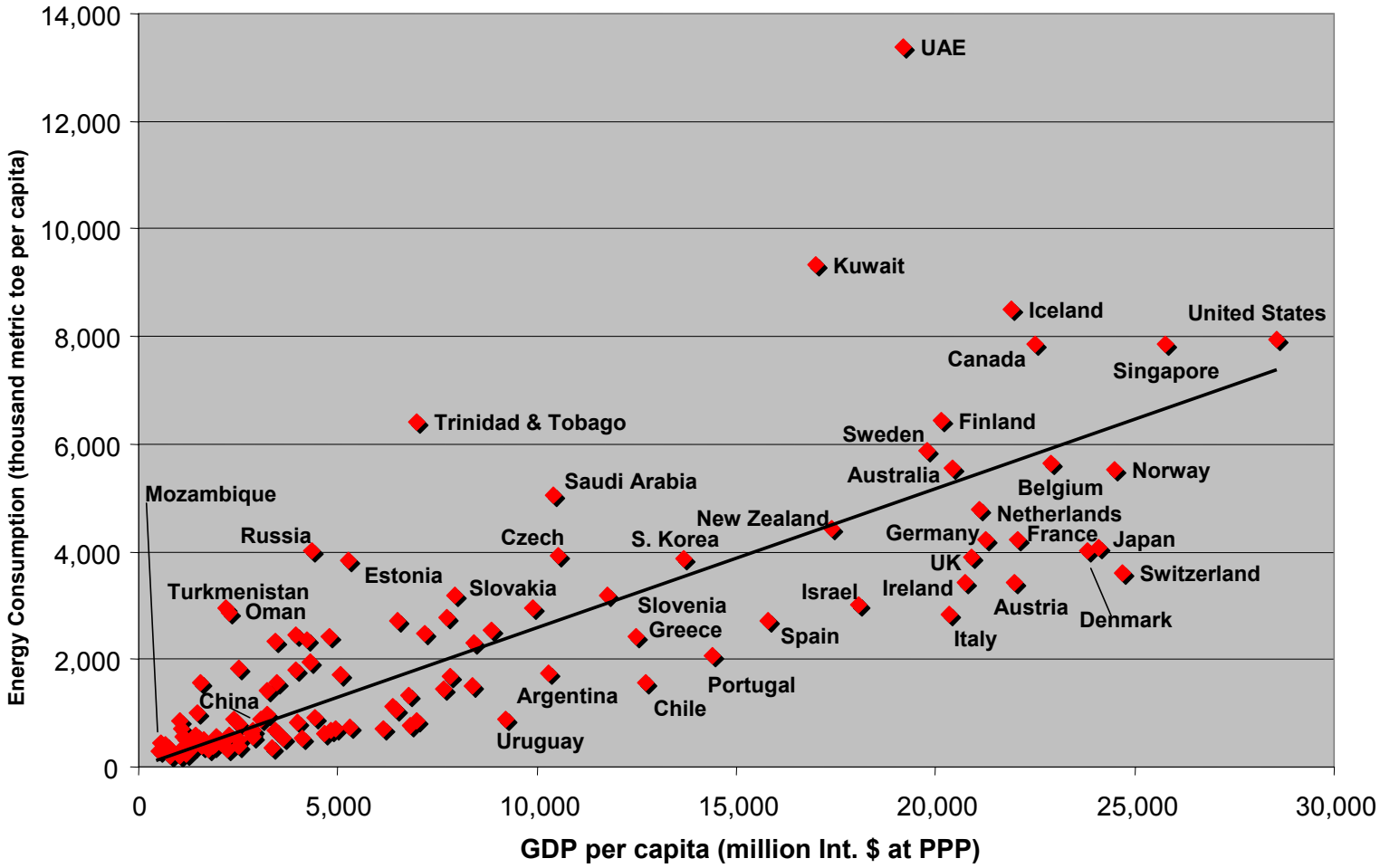
Overview

The Challenge

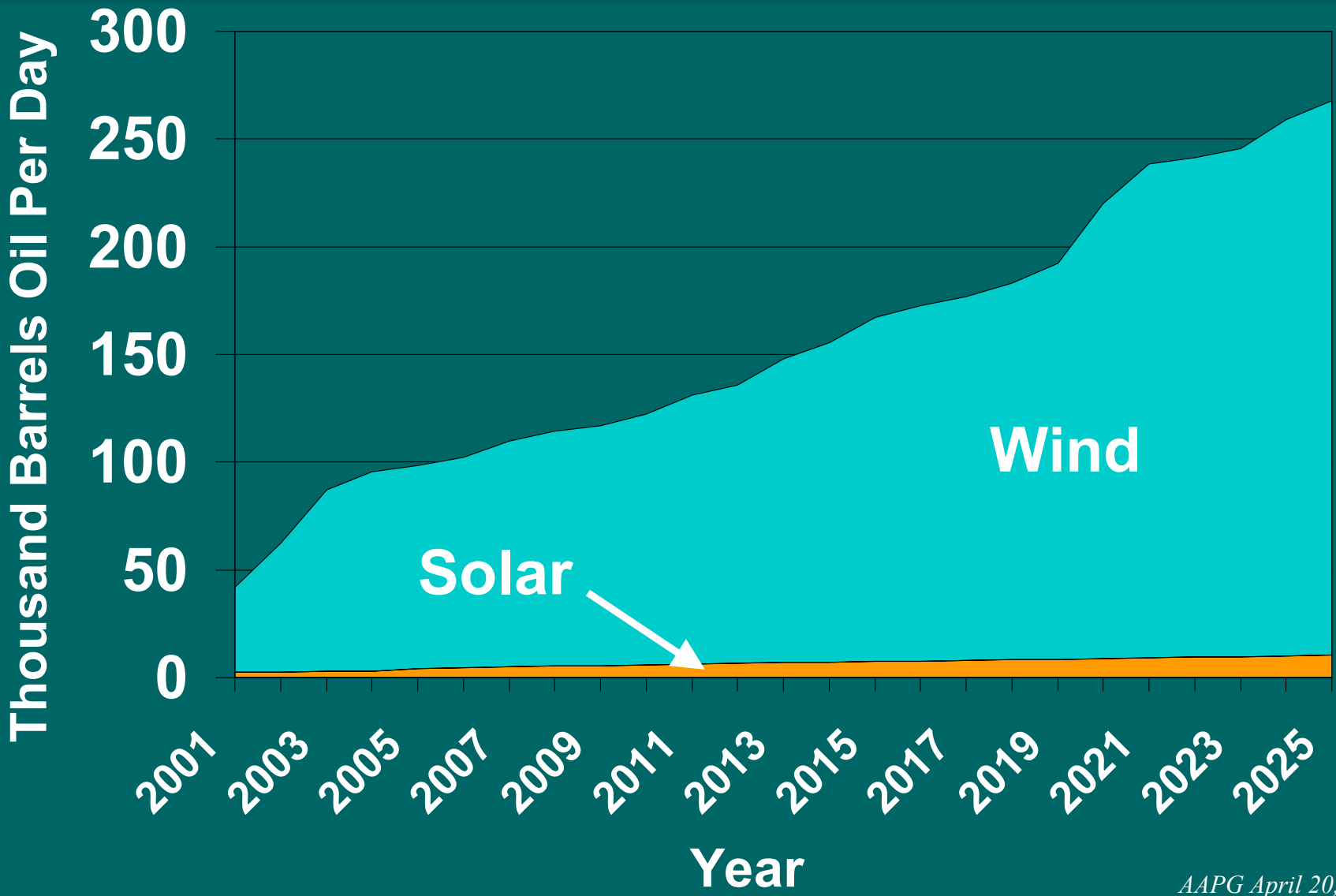
- Energy Today – 214 MMBOE/Day
  - US 45.6 MMBOE/Day
- Energy 2020 – 300 MMBOE/Day
  - US 60.2 MMBOE/Day
- Energy – Basis for Civilization
- The Technical Resource Is Adequate
- Portfolio of Energy Options
  - Technically Sound
  - Economically Sustainable
  - Significant in Size
  - Minimize Environmental Impact

World Energy

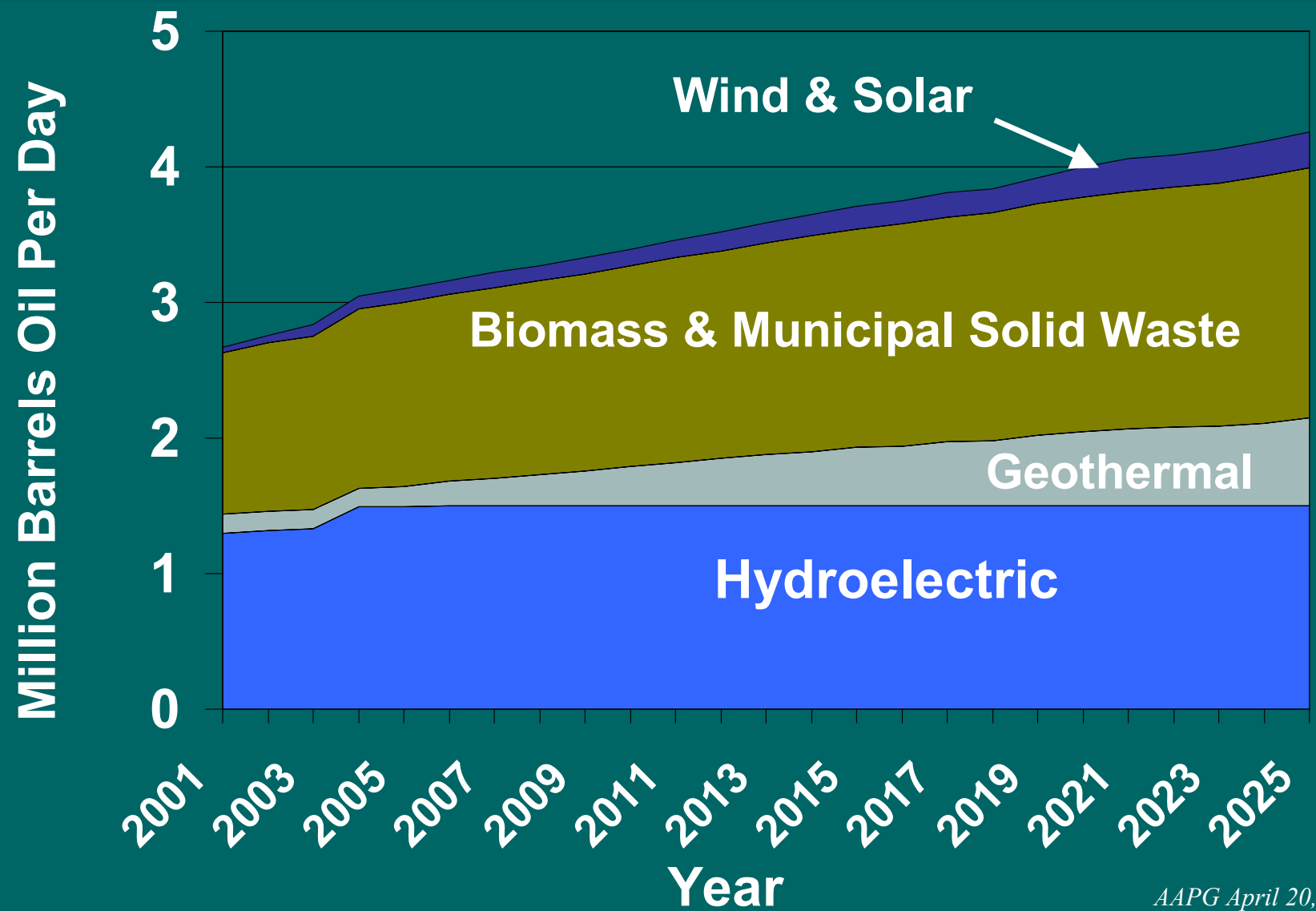
GDP vs. Energy Consumption



US Future Energy Resources



US Future Energy Resources



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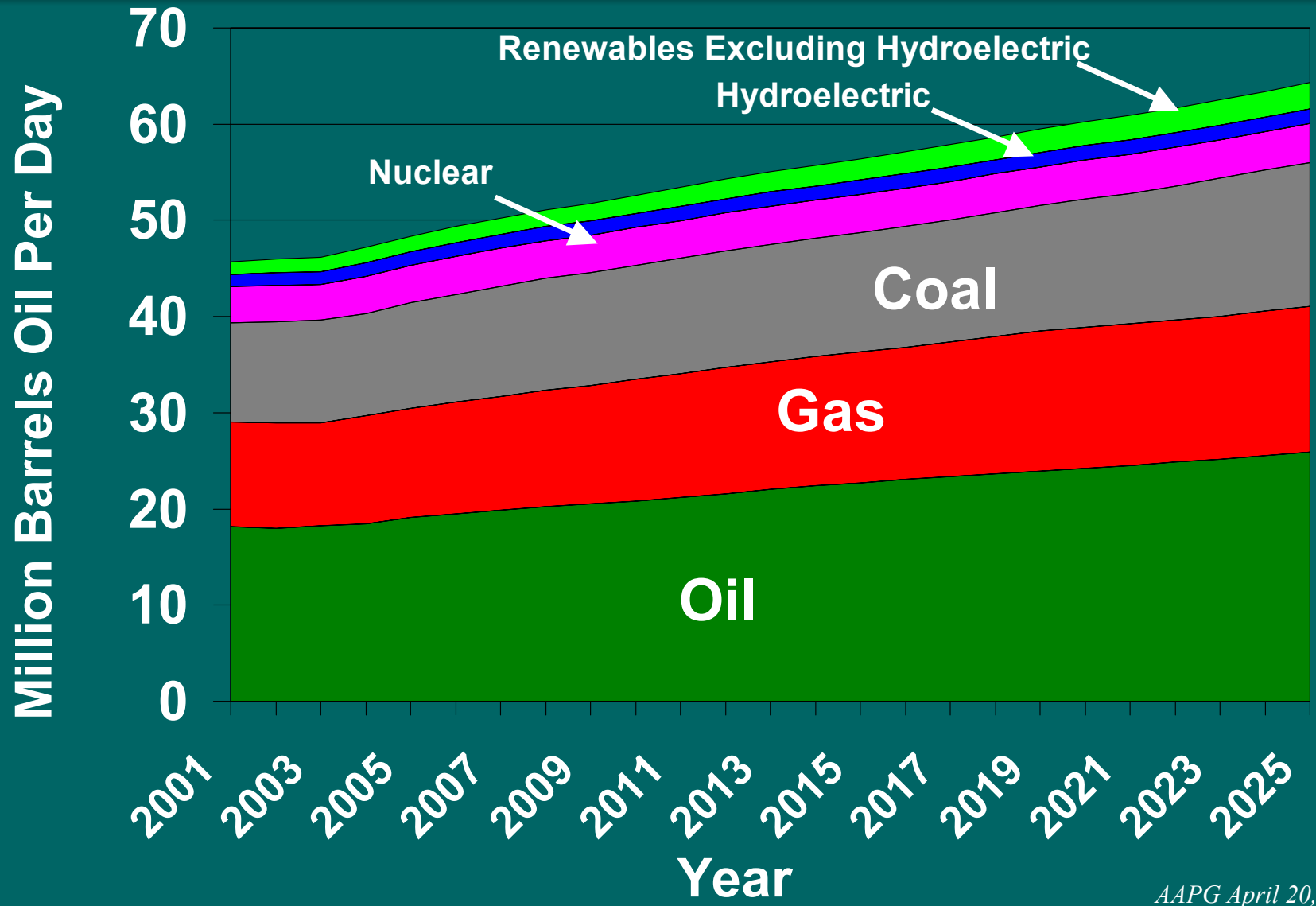
US Future Energy Resources



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Approach

- Evaluate Greenhouse Gas Resources
- Evaluate Sequestration Opportunities
- Project Goals
  - Economically Viable
  - Environmentally Sound
- Integrated Energy Systems
  - Ethanol Plants
  - Landfills
  - Cement Kilns
  - Zero Emission Power Generation (FutureGen)

CO_2 & CH_4 - The Primary GHG Contributors

United States Greenhouse Gas Emissions
(Equivalent Global Warming Basis)

CO_2
83%

Methane
9%

Nitrous Oxide
5%

HFCs, PFCs, SF_6
2%

"EIA Emissions of Greenhouse Gases in the U.S.: 2002"

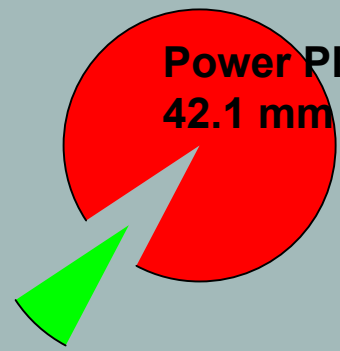
Relative Quality of CO_2 Sources

	Quality	Purity*	Quantity
Ethanol	High	99%	Low
Ammonia	High	99%	Low-Mod
Coke Gasification	High	99%	Mod-High
Meth. Reform.	Moderate	65%	Mod-High
Cement	Low	50%	Mod-High
Landfills	Moderate	42%	Mod-High
Power Plants	Low	8-12%	V. High

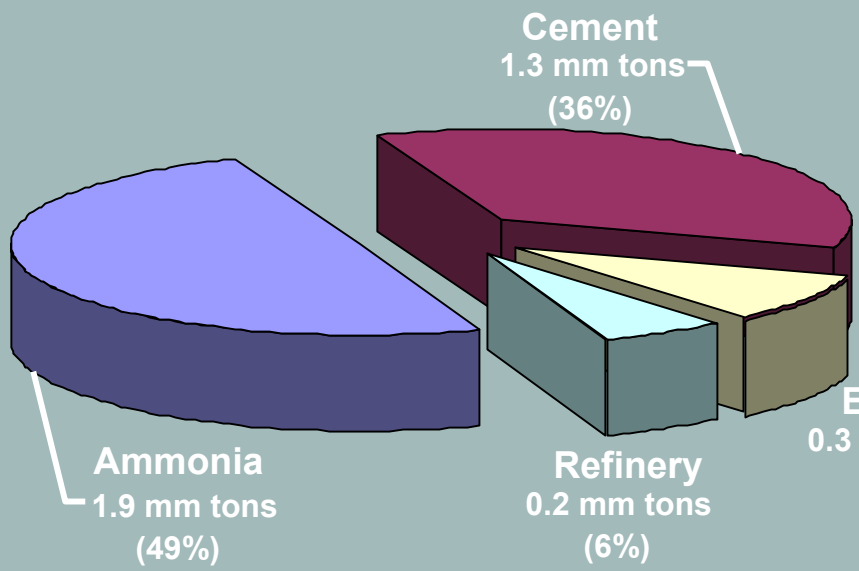
** dry weight %*

Kansas Sources for CO_2 Capture

Primary Sources

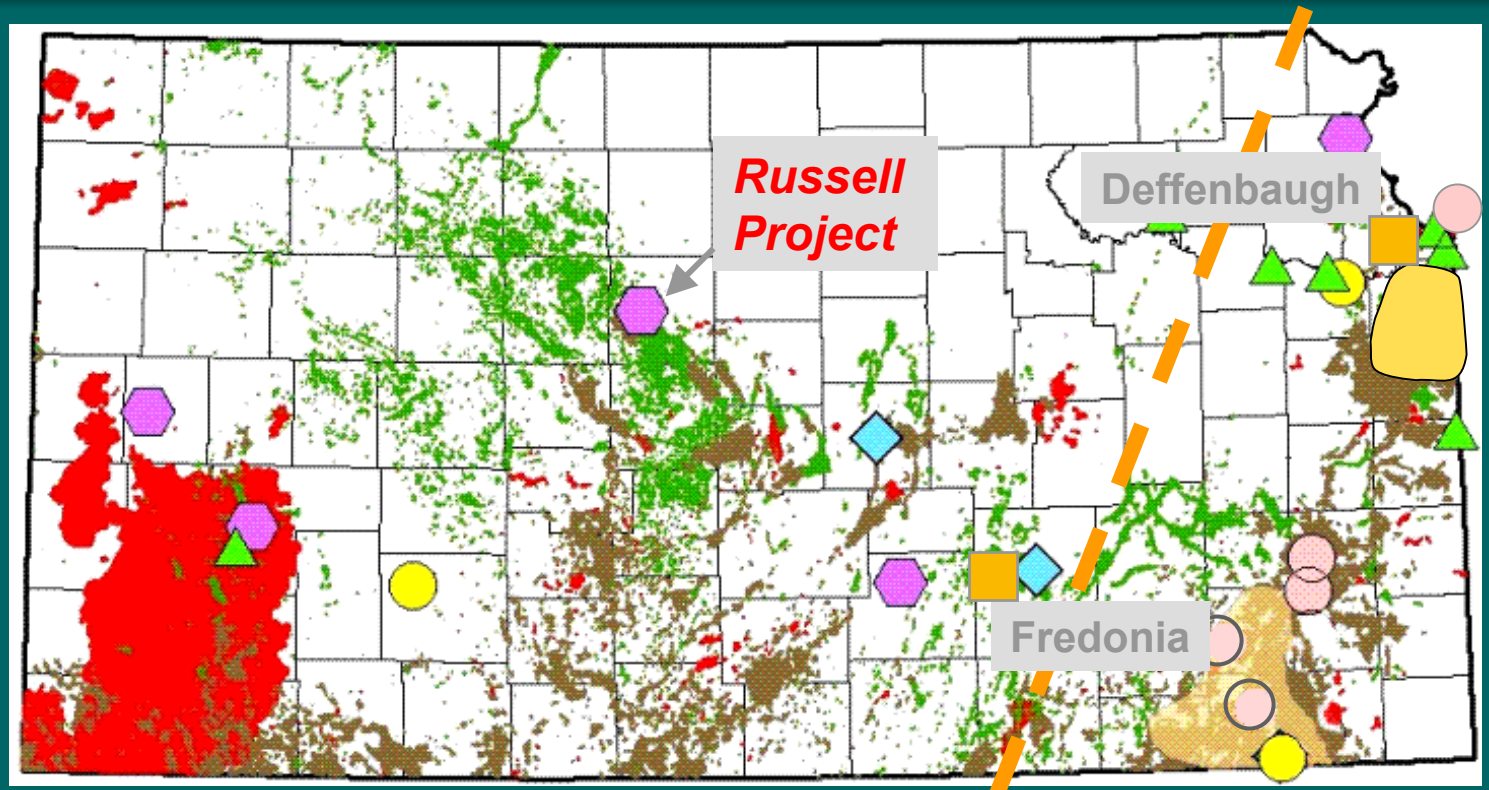


Non-combustion Sources



Annual CO_2 Emissions

Major Kansas GHG Sources



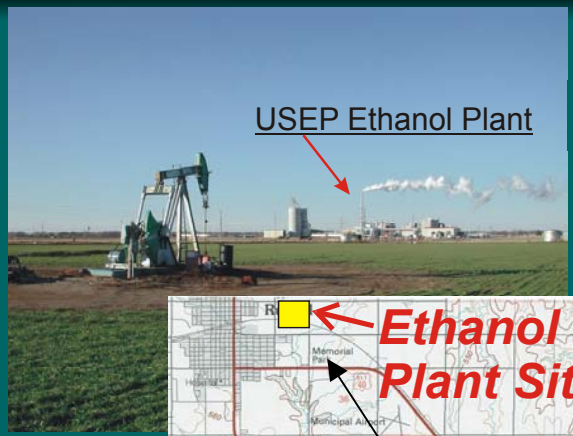
Oil and Gas Fields

- CBM
- Oil
- Oil & Gas
- Gas

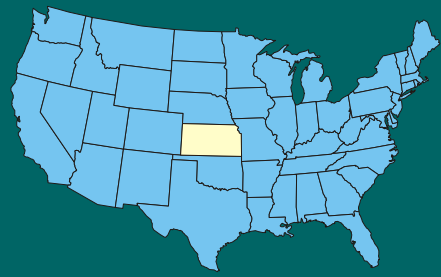
Industry

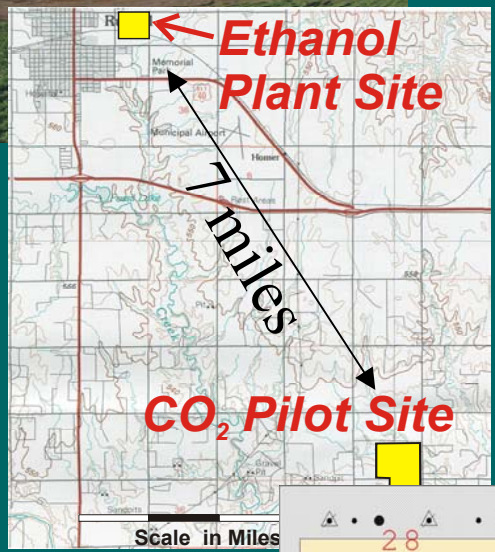
- Cement
- Ammonia
- Power
- Refinery
- Ethanol
- Landfills

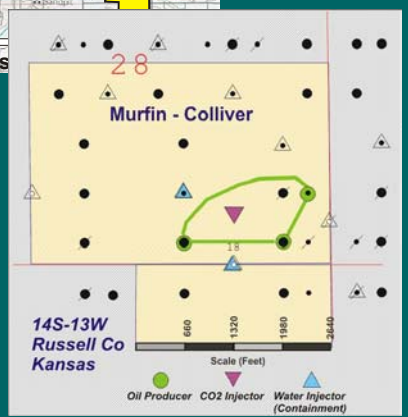
Russell, Kansas Project

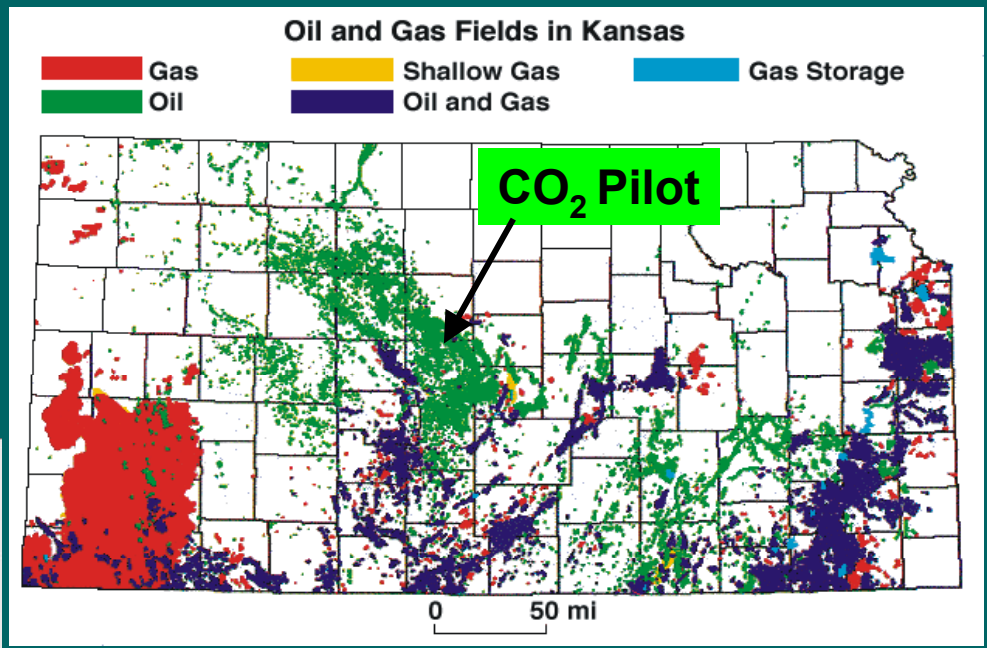


First Sequestration of Agricultural CO_2









Russell is centered in oil, grain and cattle region

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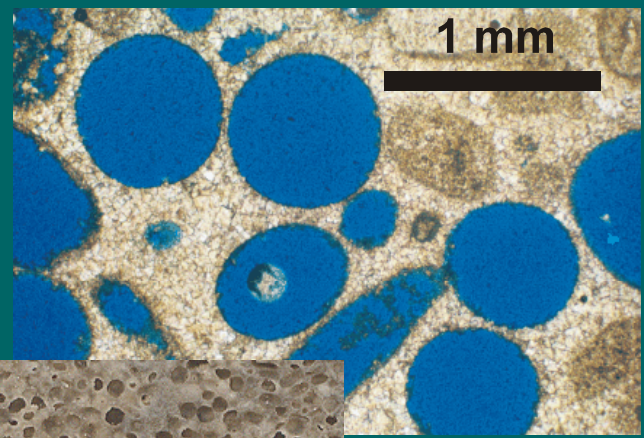
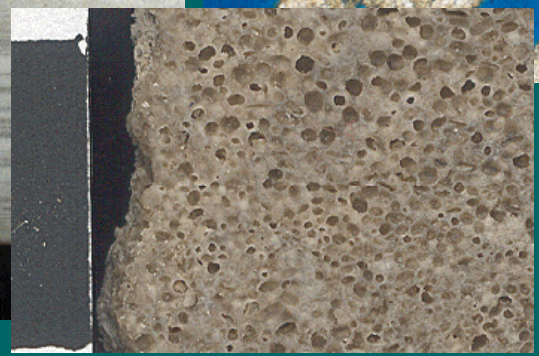
The CO_2 EOR Oil Resource

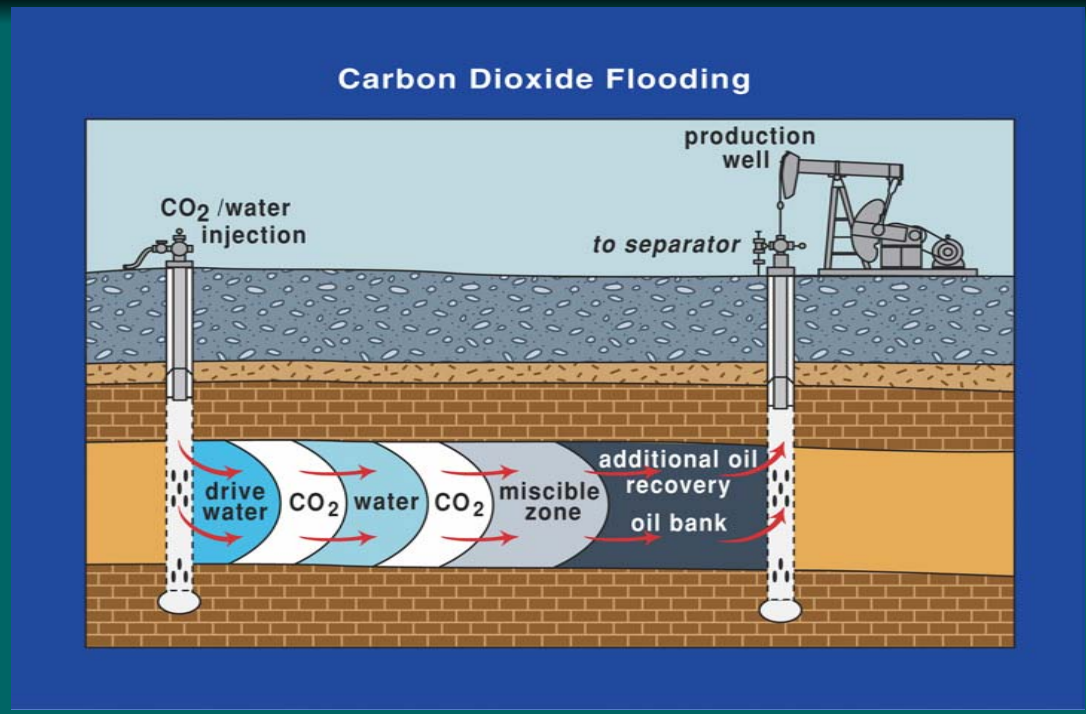
Sorw	30%
Porosity	30%
Perm.	100 md

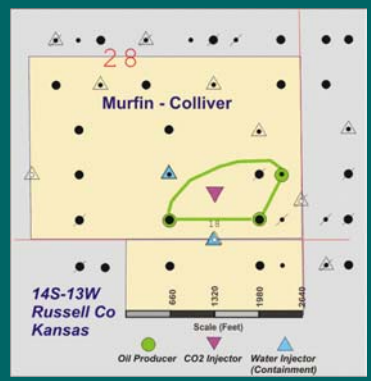




The CO_2 EOR Oil Resource

- Project Life
  - Six Years
  - Total CO_2
    - 40-60% PPV
    - 102,000+ mcf
- Injection
  - December 1, 2004
  - 32,000 mcf (1,666 mt)
  - Average Daily 240 mcf
  - Est. 120-180 Days to CO_2 Breakthrough
- Production
  - March 3, 2004
  - Current 3 BOPD
  - EUR 20,000 Barrels
- Sequestration
  - 5,209 metric tons





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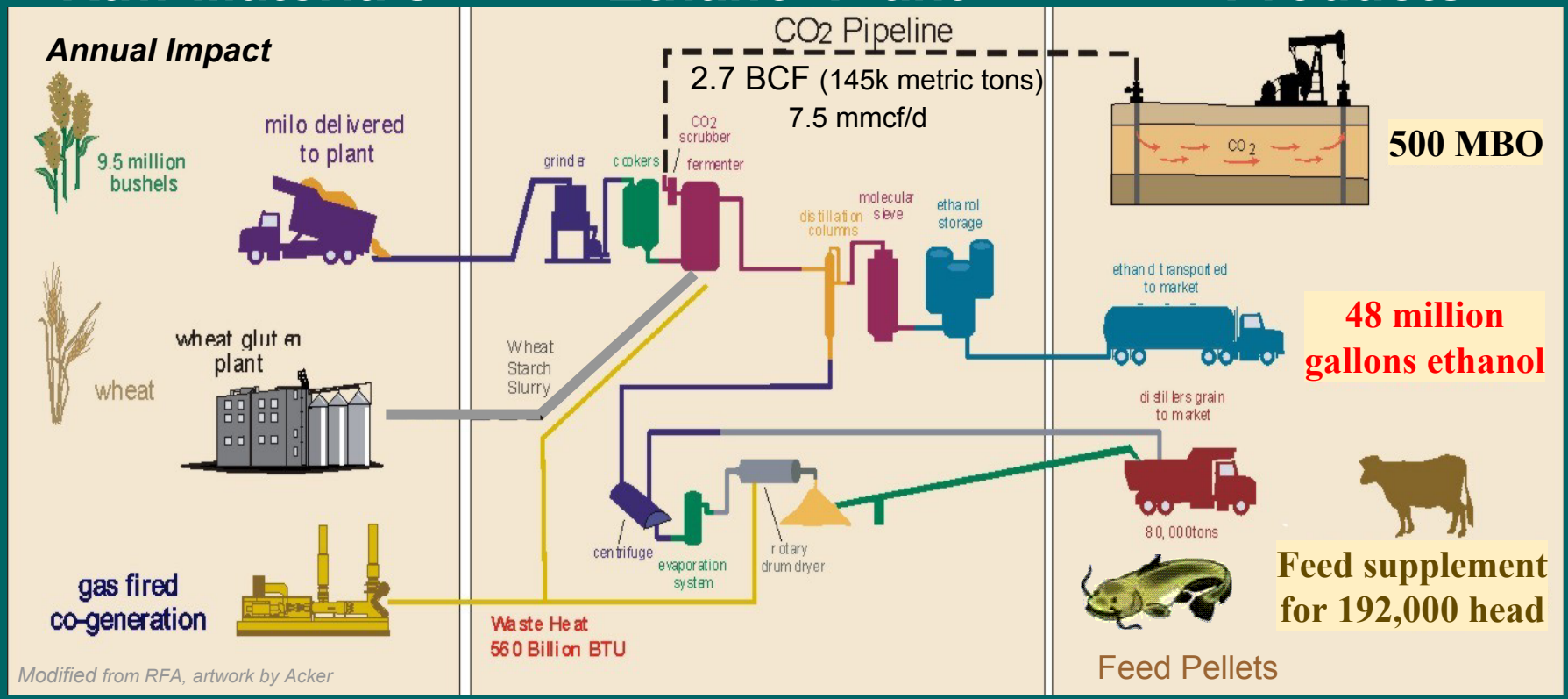
Russell Integrated Energy System

Water
One Bushel Milo
Heat
→ Fermentation →
18.5# Carbon Dioxide
2.7 Gallons Ethanol
18# Cattle Feed (DDG)

Raw Materials

Ethanol Plant

Products



1 metric ton CO_2 = 19 mcf

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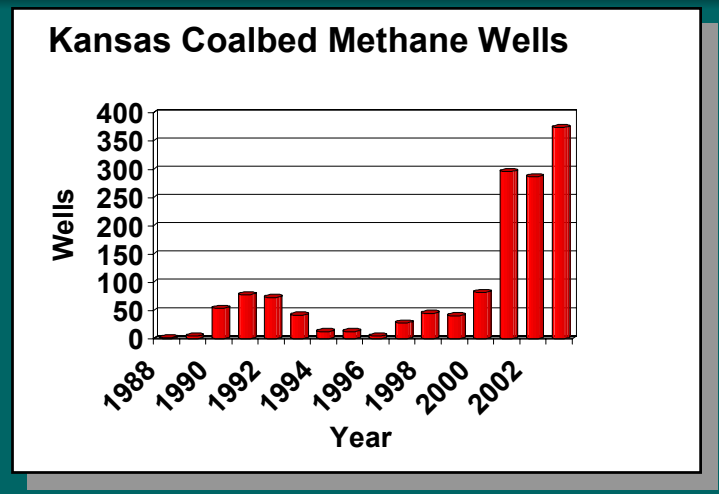
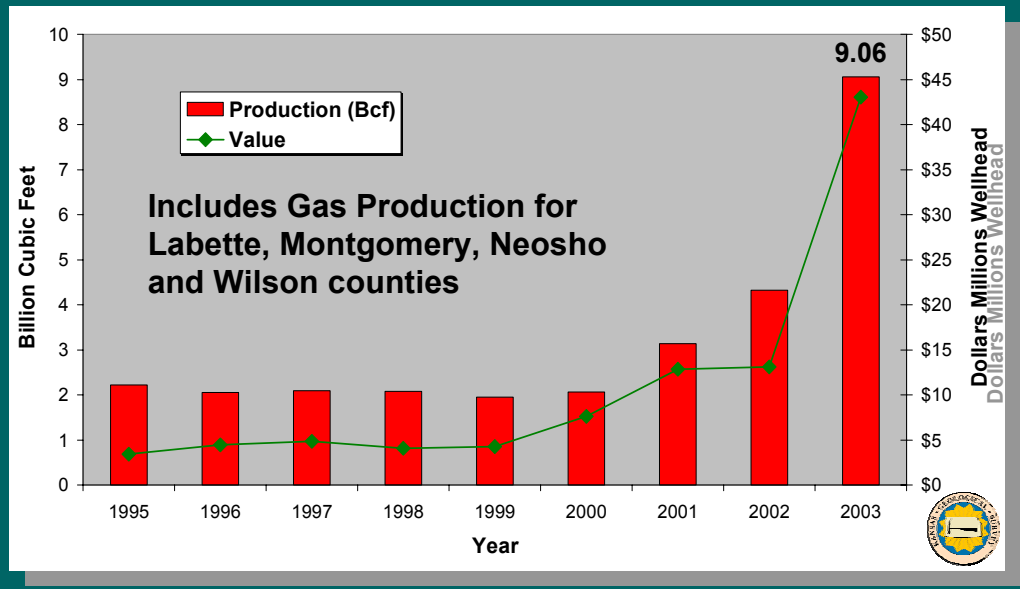
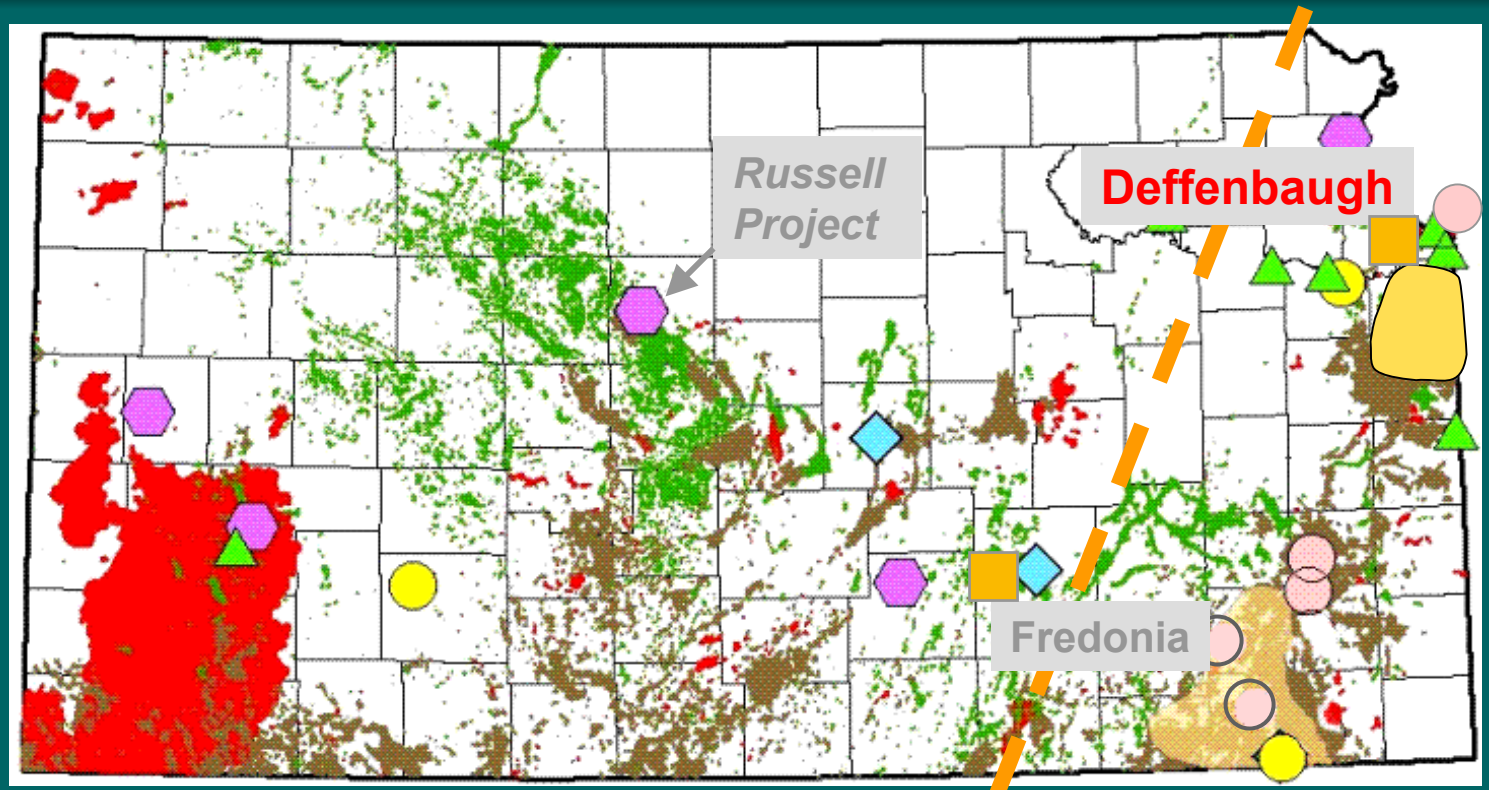
Kansas CBM Production

- Middle Pennsylvanian
  - High volatile- to medium volatile-bituminous
  - Coals < 6 ft thick
  - Depth 450 – 1300 ft.
  - Gas Content
    - Up to 360 SCF/Ton
- Activity
  - 1800 Wells
  - Estimated Annual Production
    - 10 Bcf
- Distribution
  - Southeast Kansas
- Production
  - Trace to 300+ MMcfd (average 90 Mcfd)
  - 10 to 20 BWPD per well
    - TDS typically 90,000 ppm
    - Arbuckle Disposal





Major Kansas GHG Sources



Oil and Gas Fields

- CBM
- Oil
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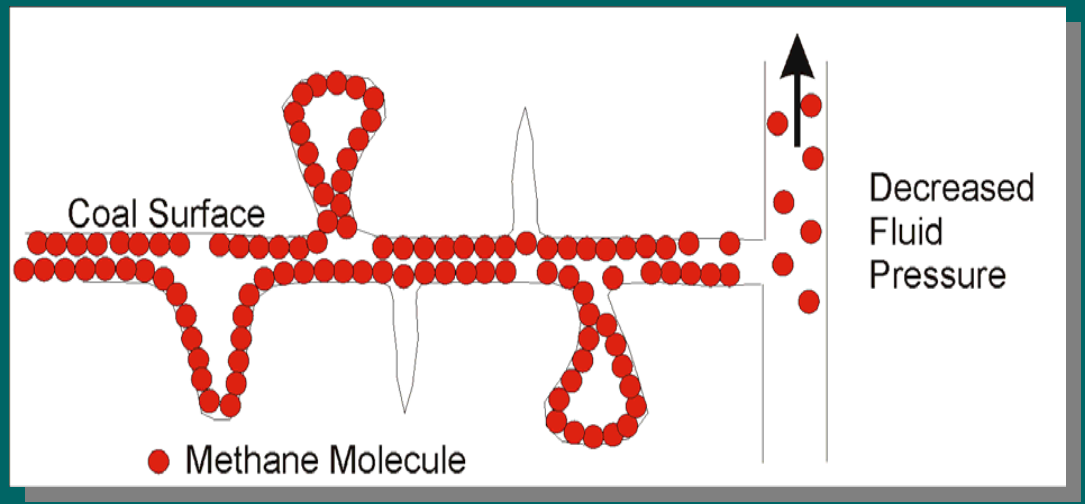
- Gas

Industry

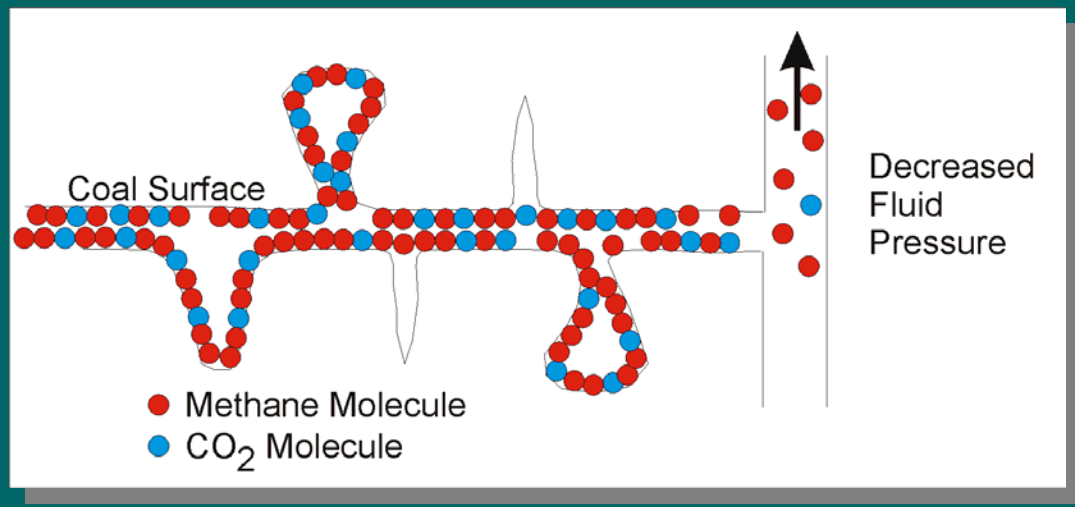
- Cement
- Ammonia
- Power
- Refinery
- Ethanol
- Landfills

Methane Production from Micropores



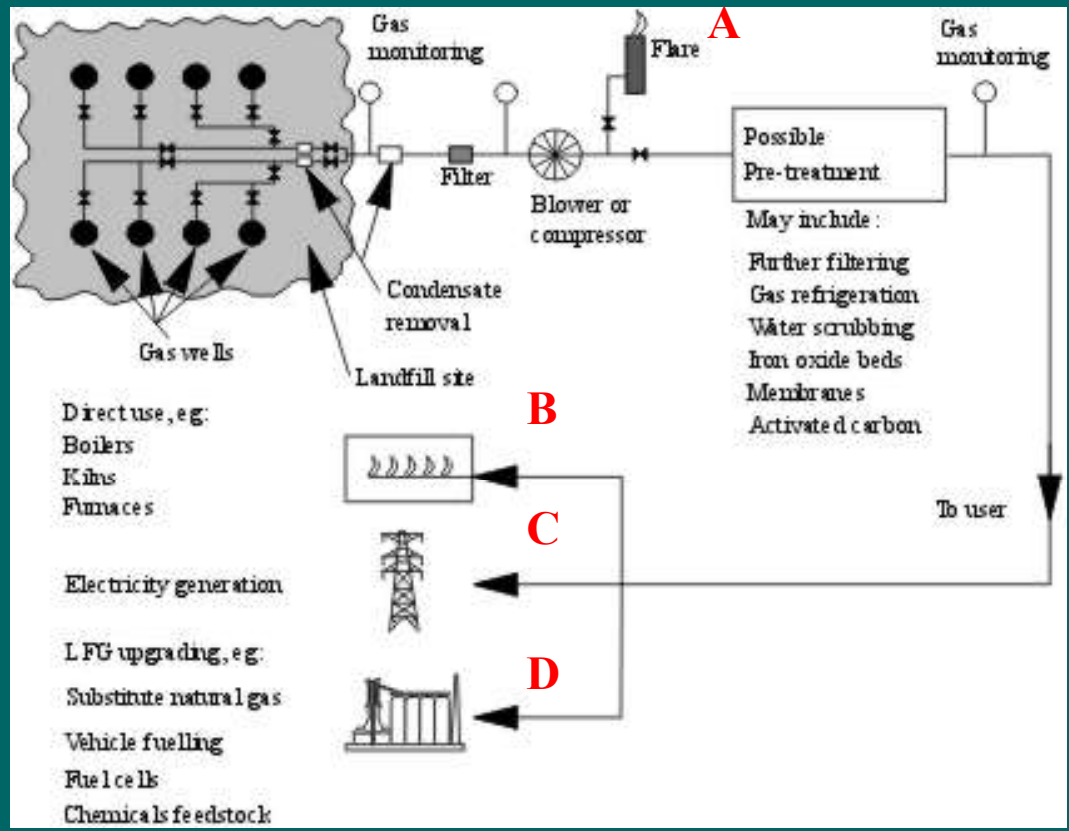
Desorption

Differential
Adsorption

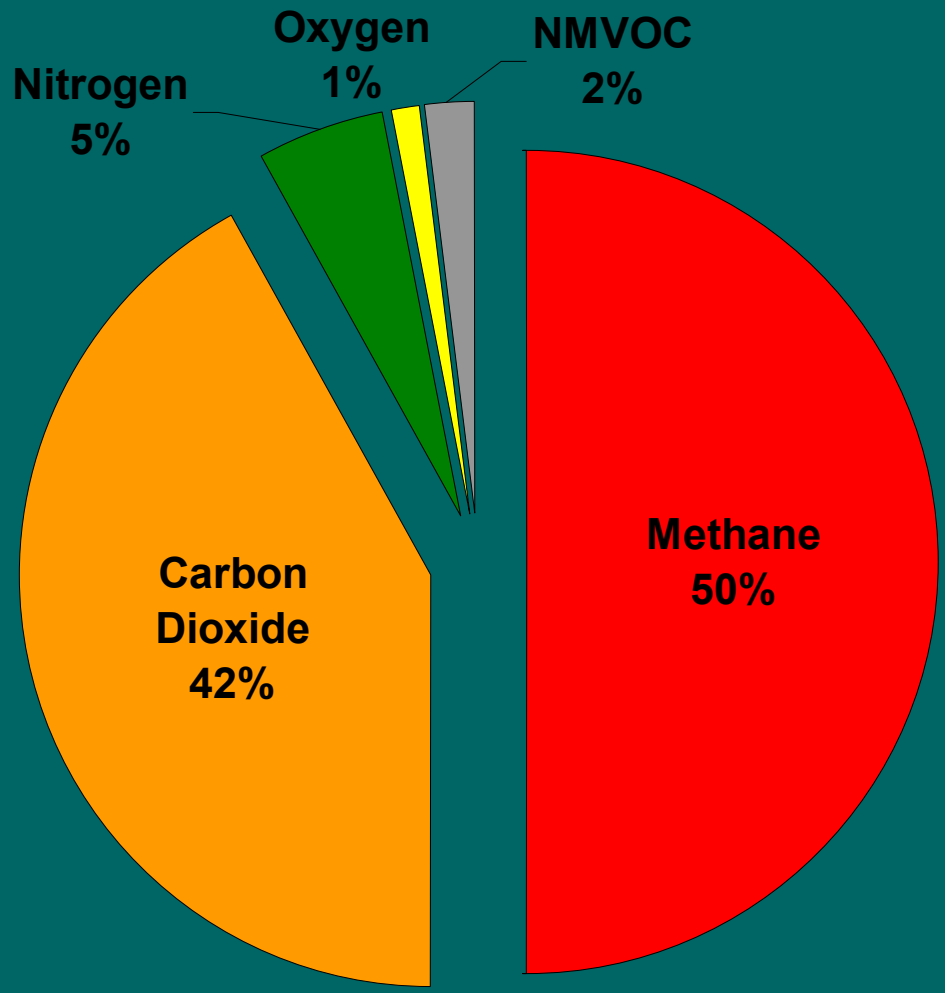


Landfill Gas

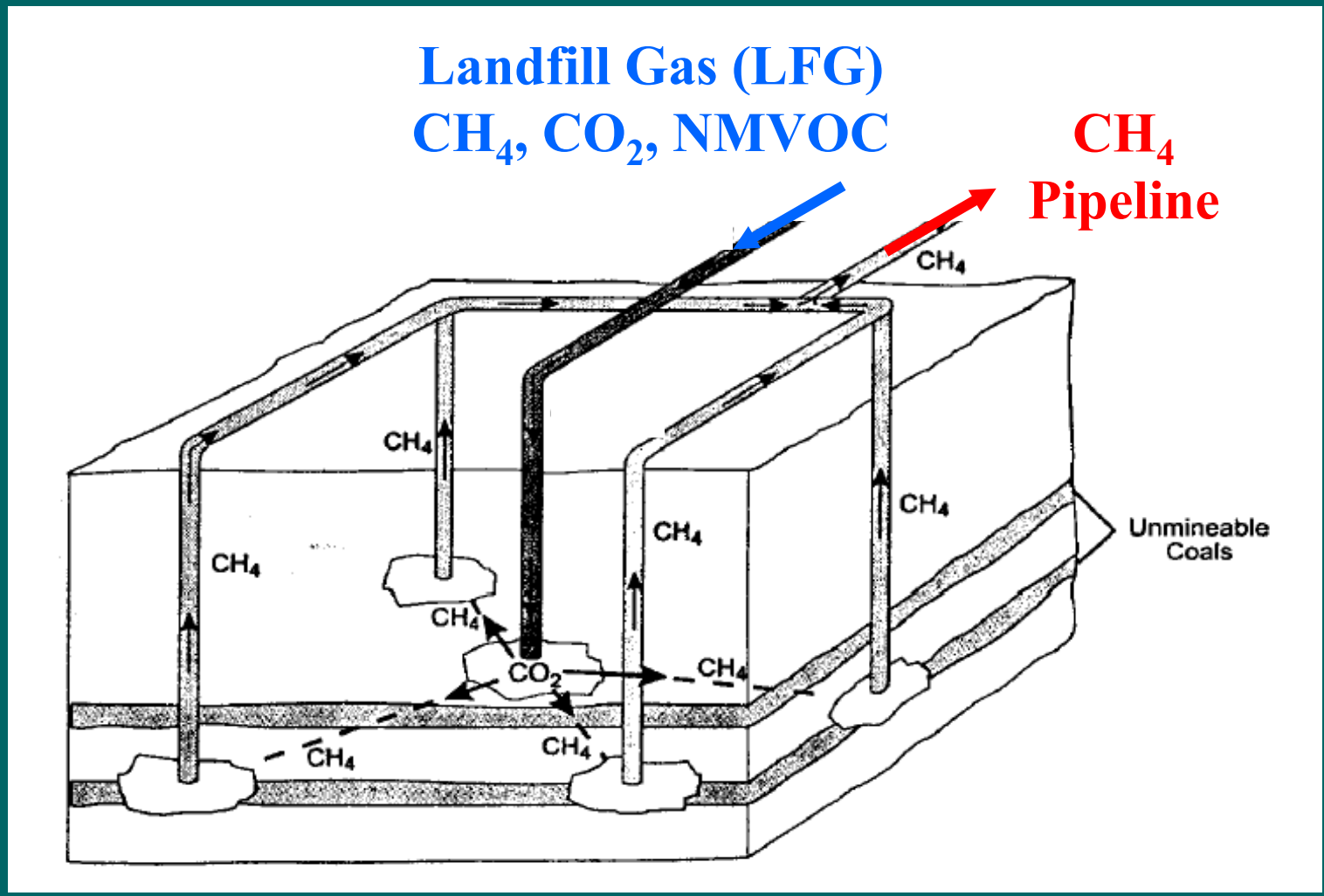
- Landfill Gas (LFG)
  - 9.3 % US Greenhouse Gas Emissions
  - 8.1 Million Metric Tons CH_4
    - 4.9 Million Captured
      2.4 Million Flared
  - $1.09 mcf subsidy
- Capture Costs
  - 12-15 Cents/Kwh
    Assuming 33% efficiency
- Deffenbaugh Facility
  - LFG 4.5 mmcf/day
    54 mmcf CO_2 equiv.
  - CH_4 1.8 mmcf/day sold
  - 116 tons CO_2 and NMVOC vented per day



Landfill Gas

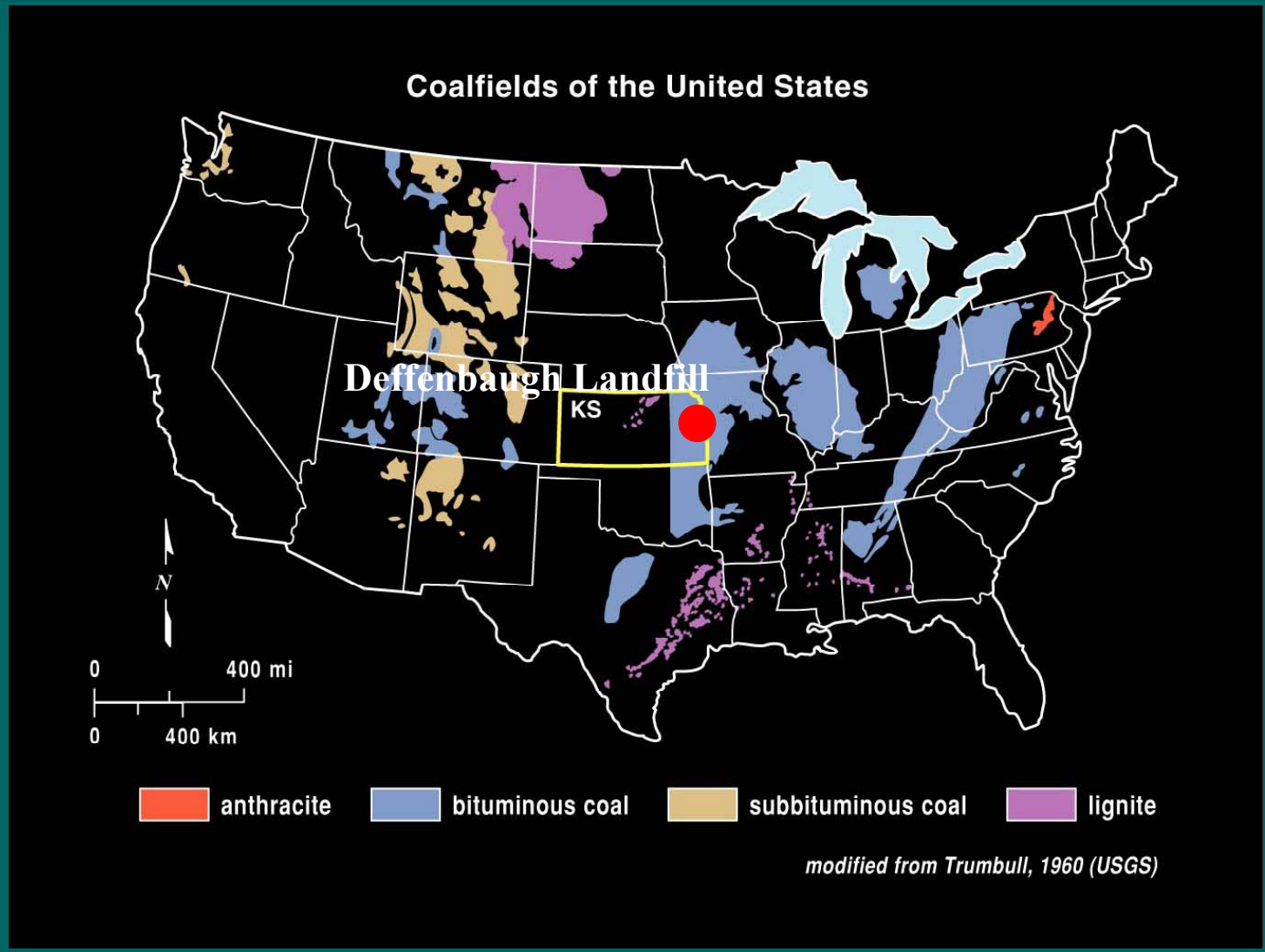


Landfill Gas



Landfill Gas

Landfill Gas



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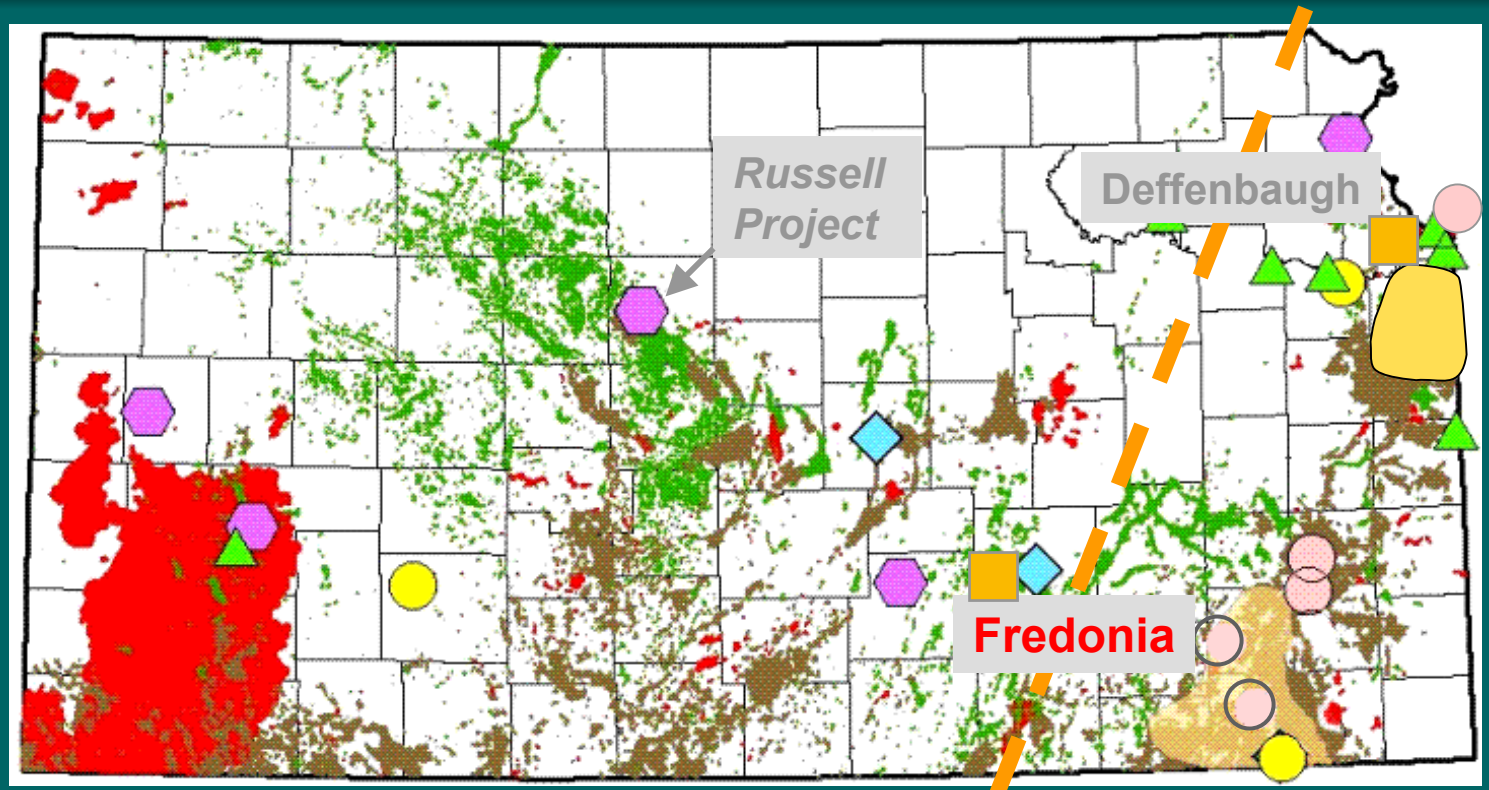

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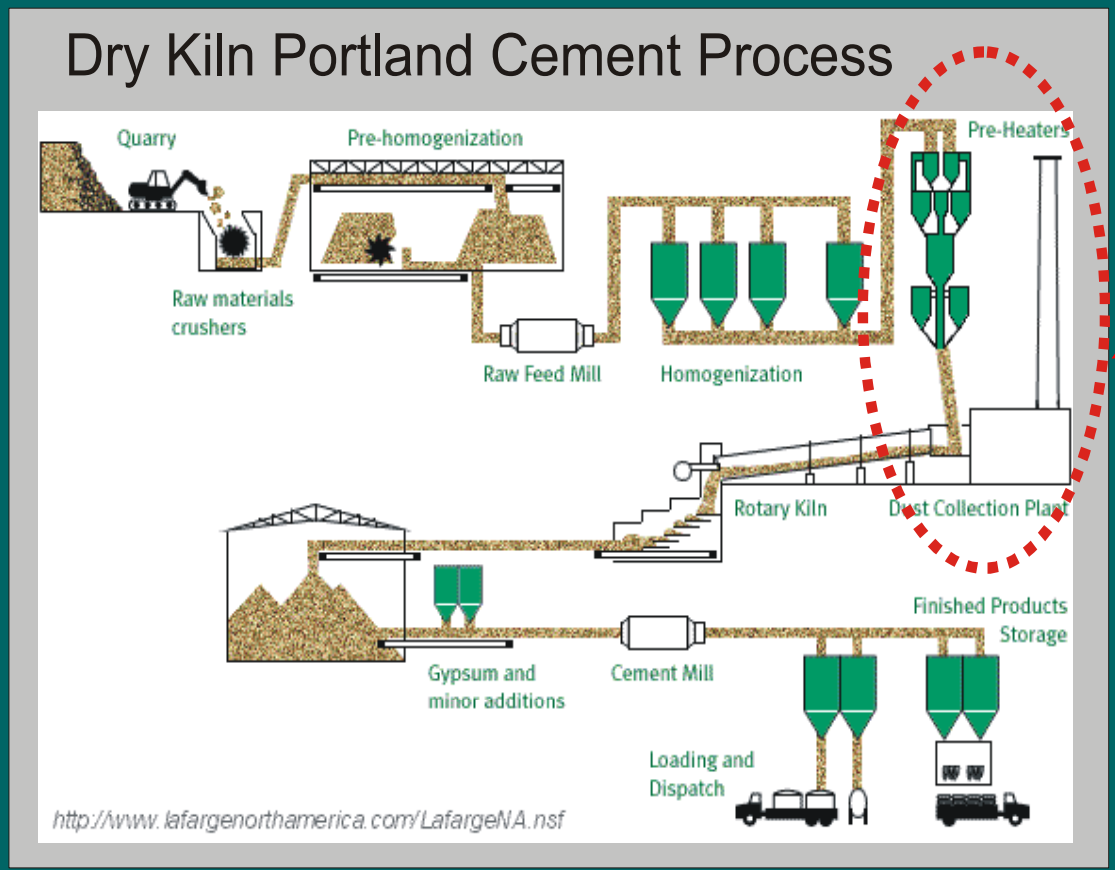
Cement Production



Calcination Process

$CaCO_3 > CaO + CO_2$

0.51 tons CO2 / ton cement

CO_2 and N_2 kiln gas mix may be suitable for ECBM with little processing

Fredonia Flue Gas and Potential SE Kansas Markets

Present Composition

	% Weight
N_2	47.3%
H_2O	22.6%
CO_2	19.3%
O_2	10.6%
	99.8%

5000 tons/day at 332° F (167° C)

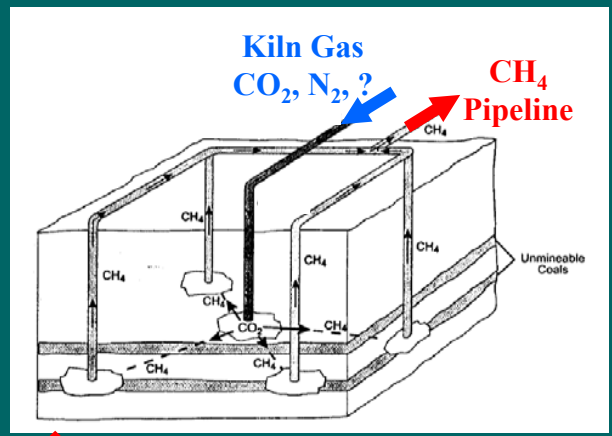
Dehydrate

	% Dry Weight	% Dry Volume
N_2	61%	69%
CO_2	25%	18%
O_2	14%	13%

Reduce Air Leaks

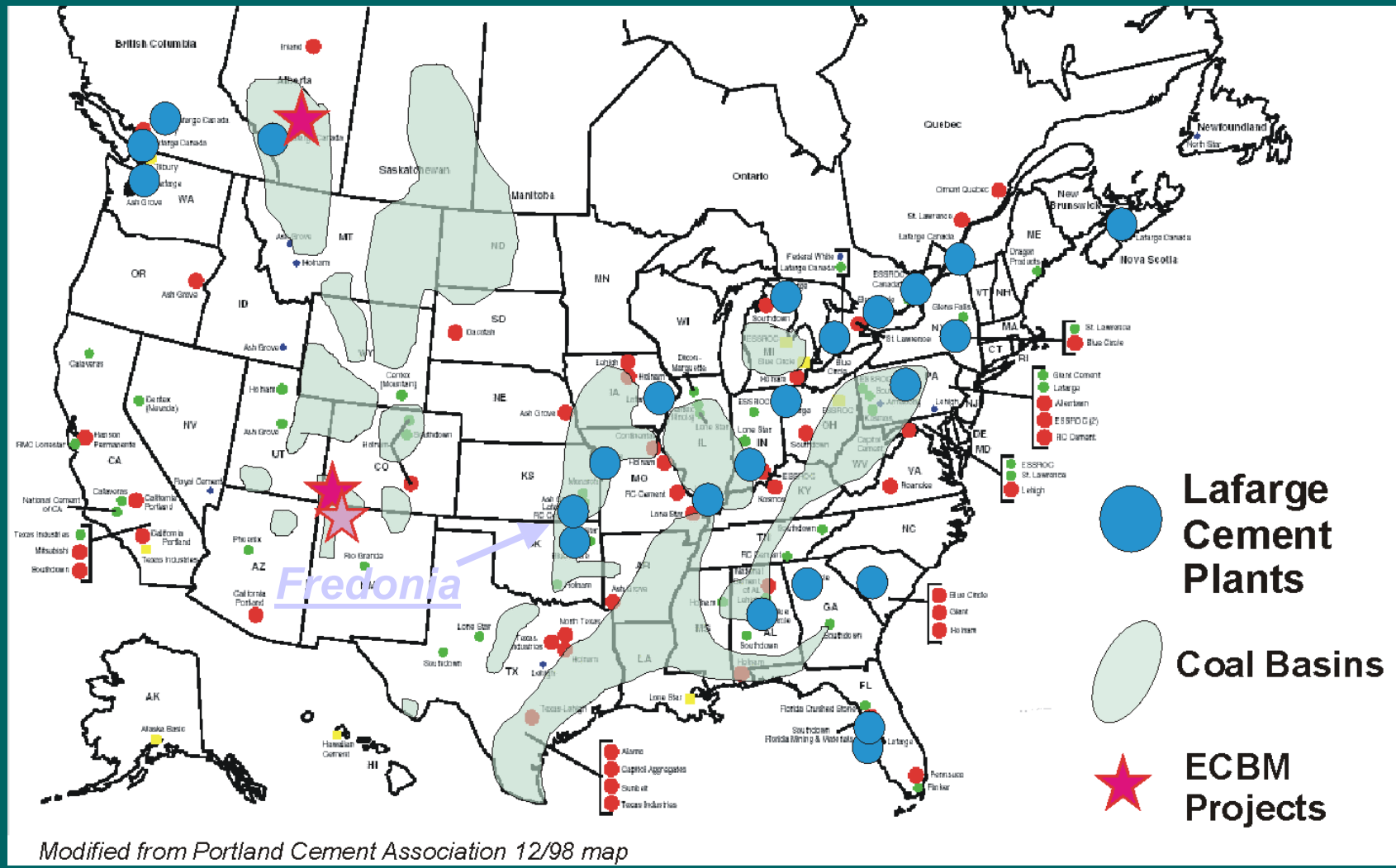
	% Dry Weight	% Dry Volume	Annual Vol.
N_2	46%	57%	8.1 BCF
CO_2	50%	39%	5.7 BCF
O_2	4%	4%	0.6 BCF

Enhanced Coalbed Methane(ECBM)

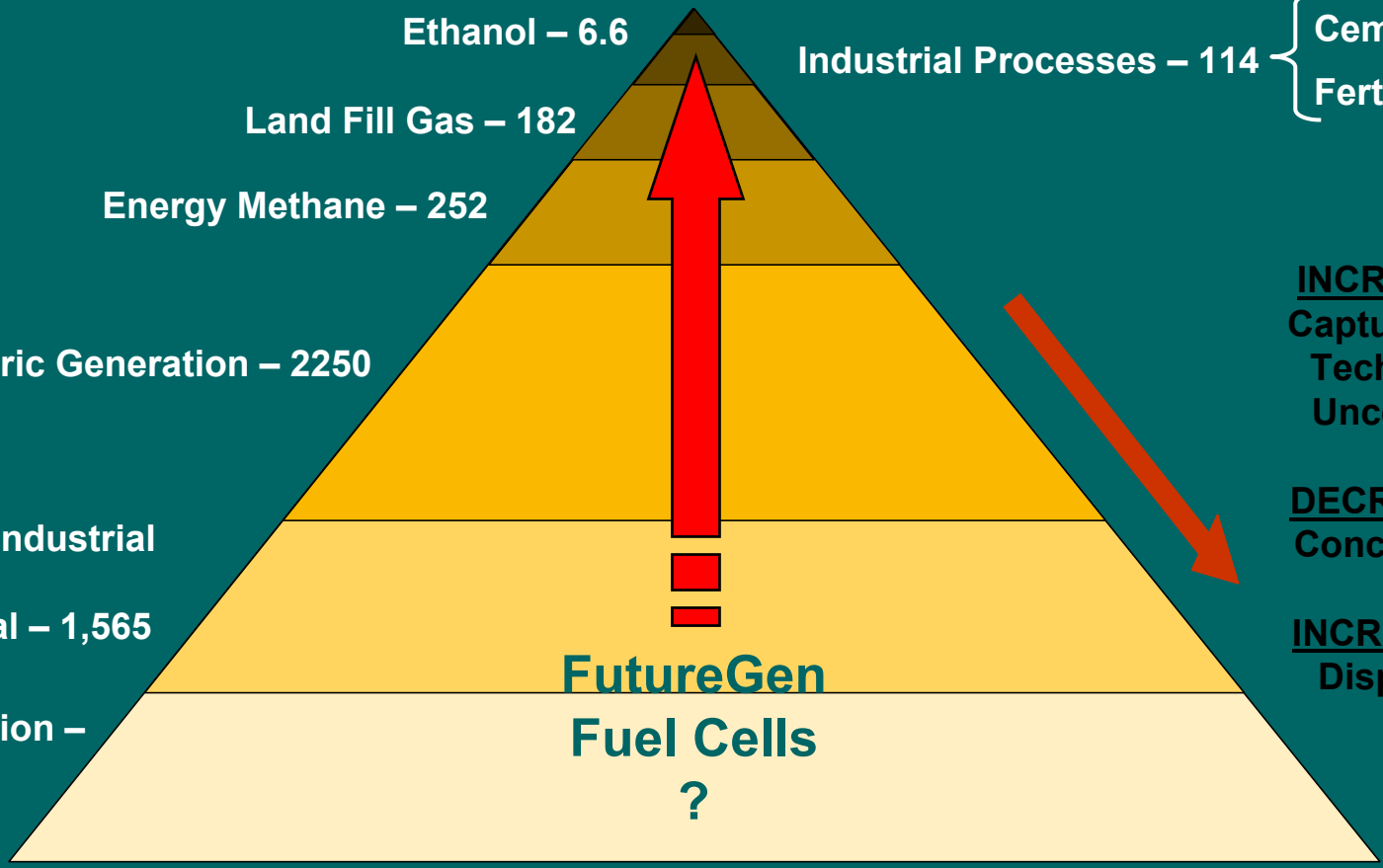


Direct or Modified

Cement Plants and Coal Basins



Greenhouse Gas Resource



Industrial Processes – 114
- Cement - 43
- Fertilizer - 39

INCREASING
Capture Costs
Technology
Uncertainty

DECREASING
Concentration

INCREASING
Dispersion

Agricultural Methane – 183
Nitrous Oxides – 333
HFC, PFC, SF_6, etc. - 121

Total GHG Emissions 6,869 Million Metric Tons

Data: Year 2002 Energy Information Agency and Renewable Fuels Assoc.

FutureGen

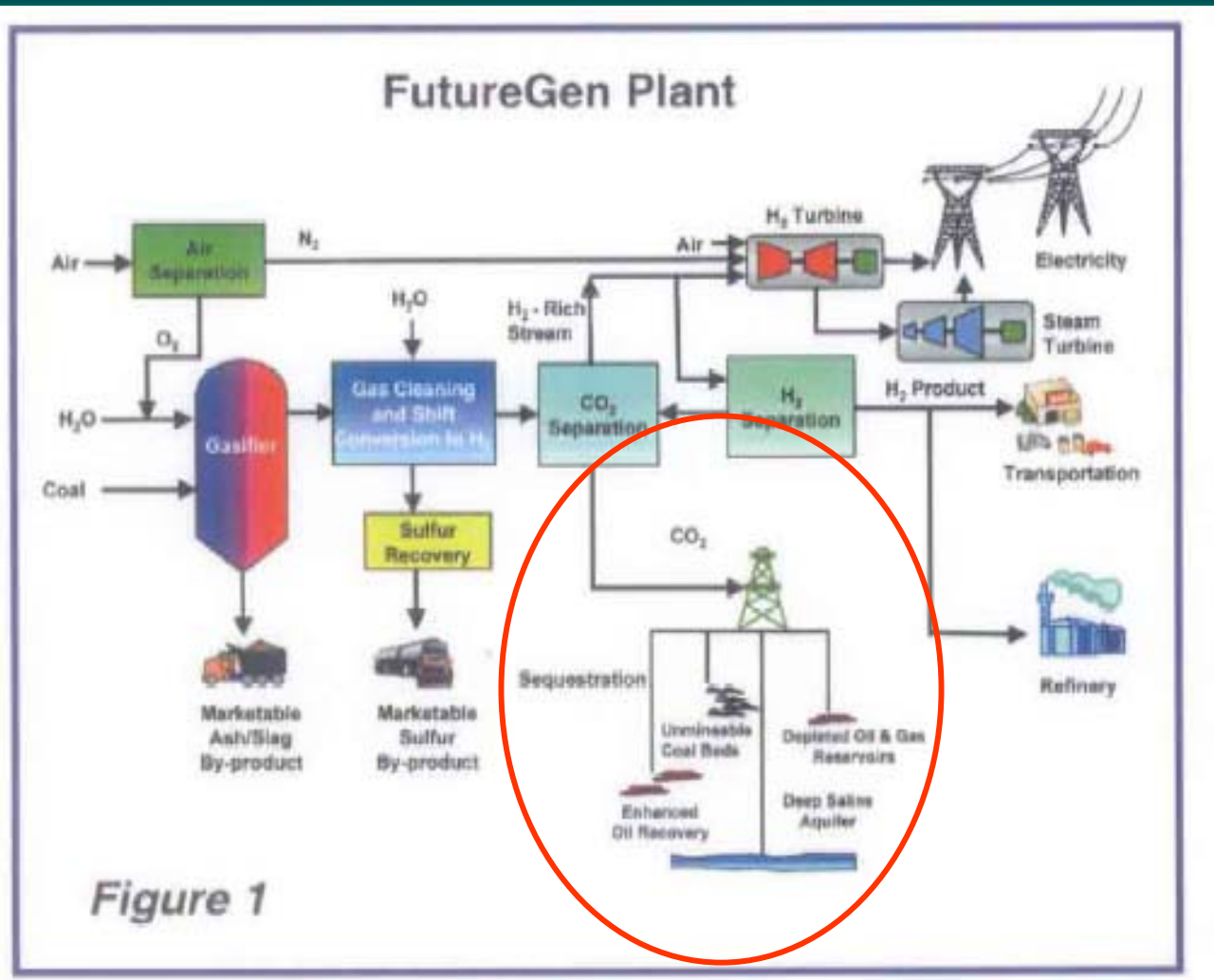
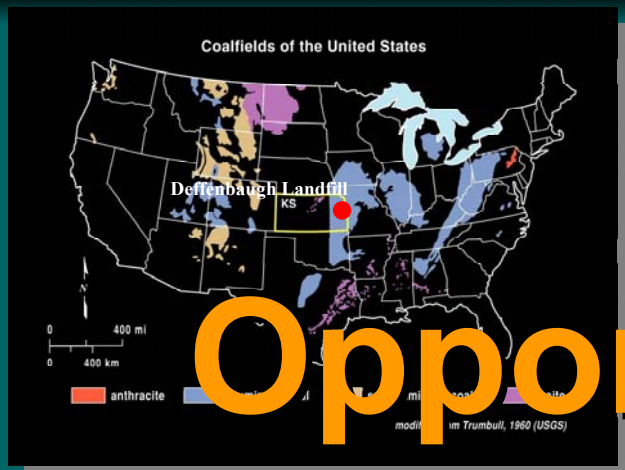
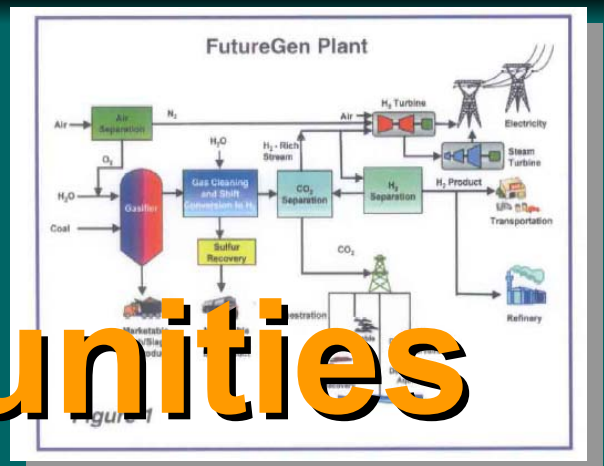


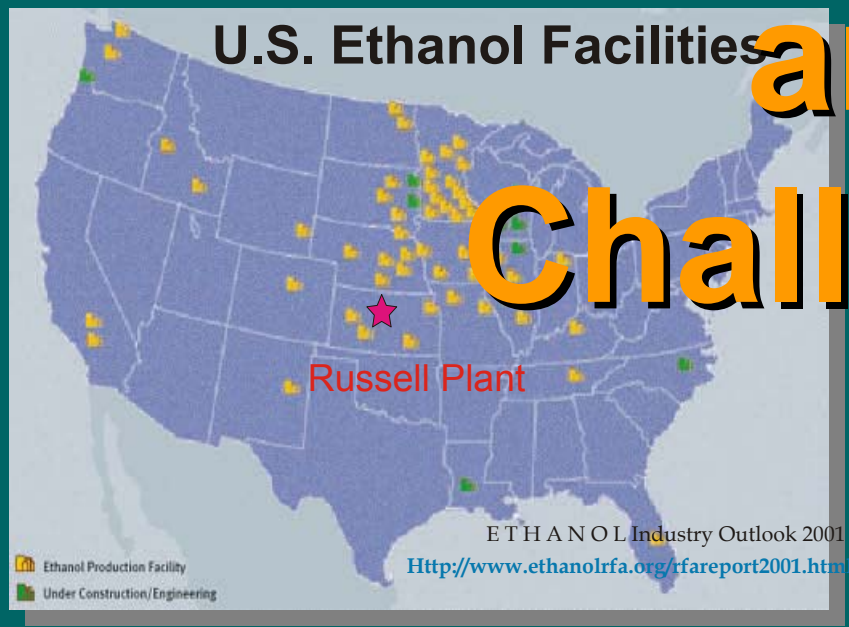
Figure 1

Potential Energy Systems

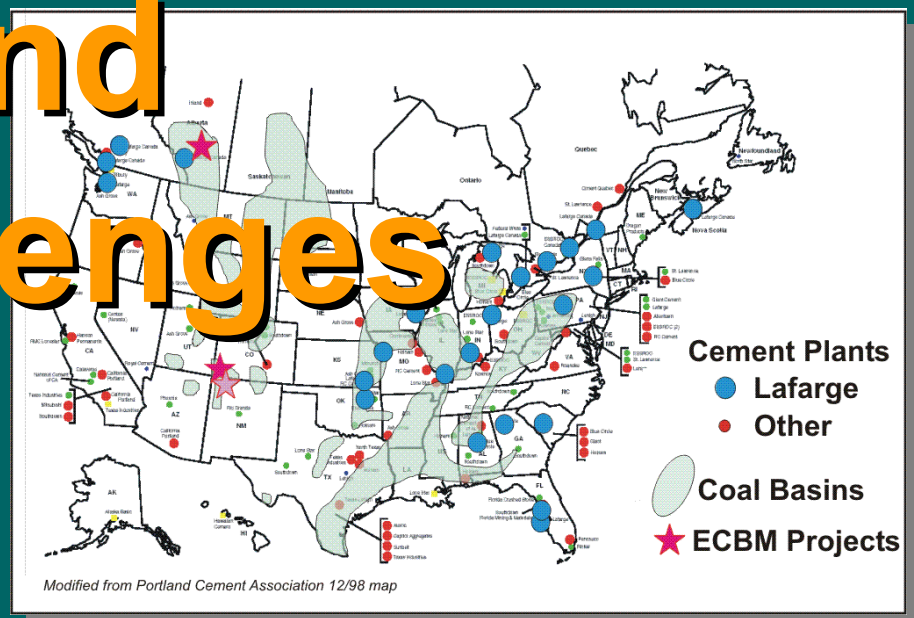




Opportunities and Challenges



E T H A N O L Industry Outlook 2001
Http://www.ethanolrfa.org/rfareport2001.html



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