Co-generation, Ethanol Production and CO_2 Enhanced Oil Recovery

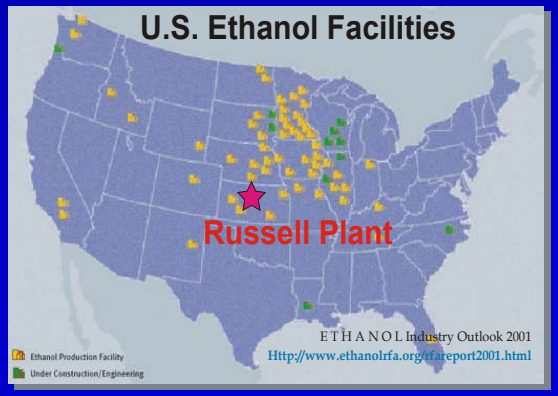
Model for Environmentally and Economically Sound Linked Energy Systems

NETL Second National Conference on Carbon Sequestration
May 7, 2003

Martin K. Dubois, Scott W. White, Timothy R. Carr

Ethanol CO_2 and Enhanced Oil Recovery

- **Ethanol production to double by 2005.**
- **Some new plants near mature oil reservoirs without nearby CO_2 source**
- **CO_2 emission reduction interest is increasing**
- **Potential to increase domestic energy production**



Opportunity for "Value-Added" geologic CO2 sequestration

Outline

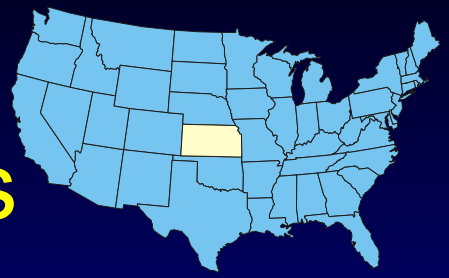
Russell Kansas linked systems pilot project

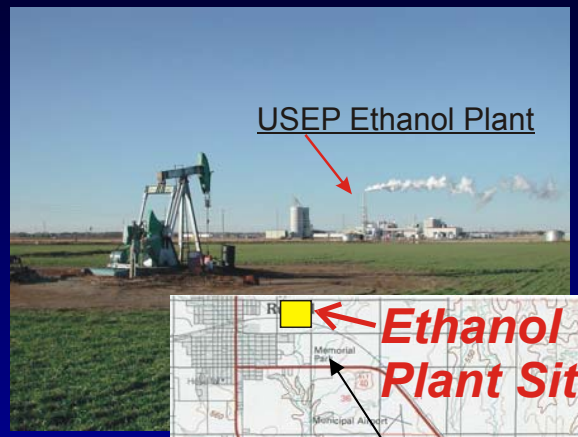
1) History and details of the linked systems in Russell
2) Details of DOE funded enhanced oil recovery (EOR) project
3) Economies created by linked systems
4) Projected economics for expansion to commercial scale CO_2 EOR.
5) Scalability and constraints of the model. Expanding interest in concept.

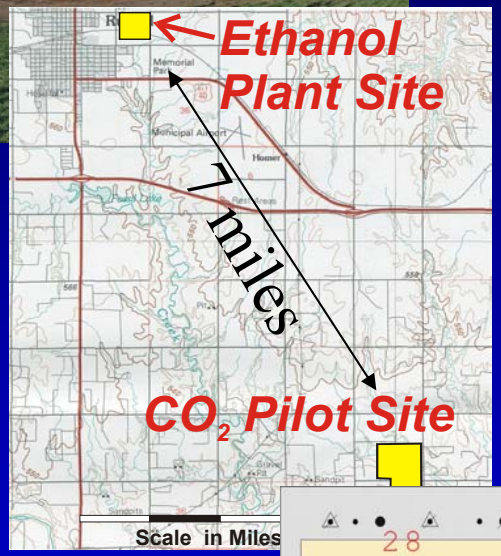
Potential linkage in other systems

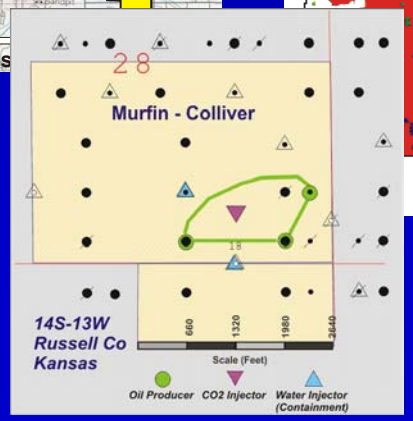
1) Other highly concentrated CO_2 "low hanging fruit"
2) Less concentrated CO_2 mixtures *(used as is)*

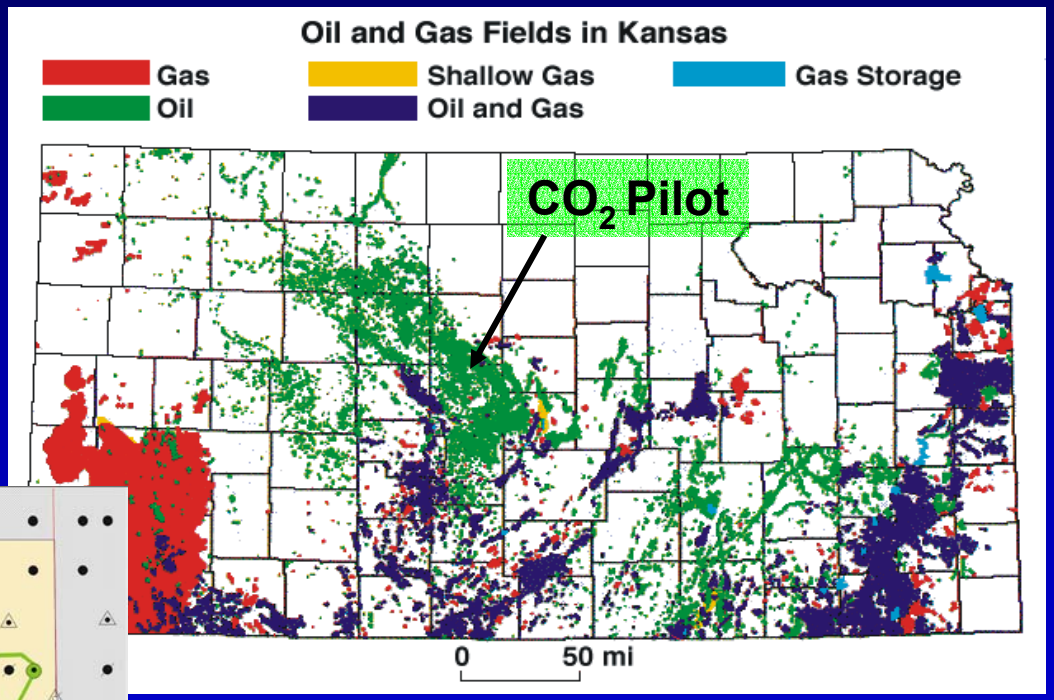
Location
Russell, Kansas











Centered in oil, grain and cattle region

Fortuitous, Independent Events May Lead to Linkage of Three Energy Systems

2000 DOE funded CO_2 enhanced oil recovery (EOR) demonstration project 7 miles SE of Russell

2000 City of Russell electrical plant explosion destroyed 75% of diesel fired generation capacity.

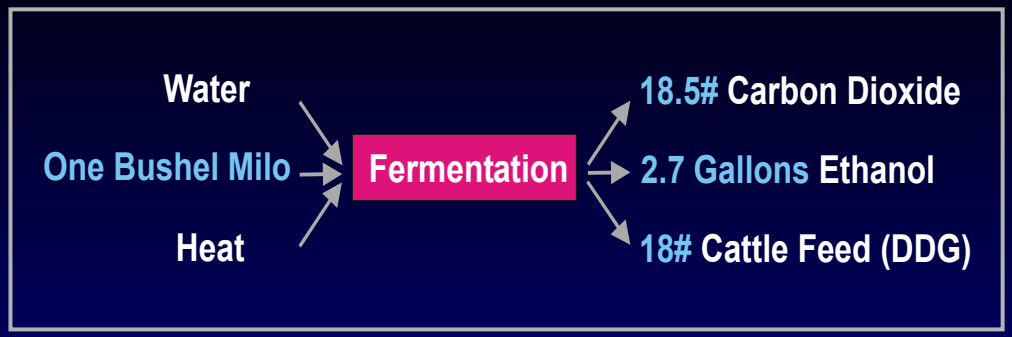
2001 ICM, Inc. with U.S. Energy Partners (USEP) builds ethanol plant. Agreements made for co-generation and providing CO_2 for EOR pilot project.

Other events

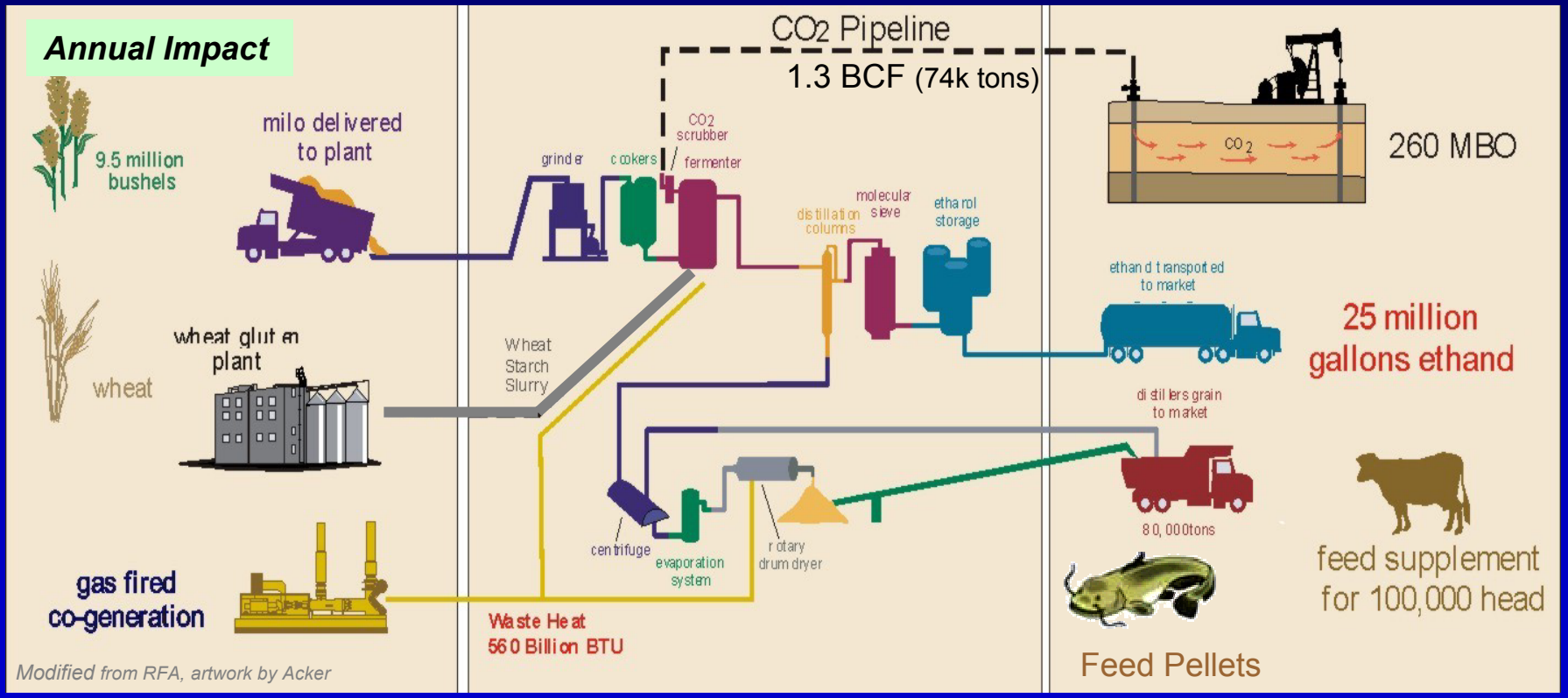
2002 Gluten plant slurry pipeline added and ethanol plant expanded to 40 million gallons

2003 CO_2 EOR pilot project to begin injecting CO_2

Russell's Linked Energy System



Raw Materials | Ethanol Plant | Products

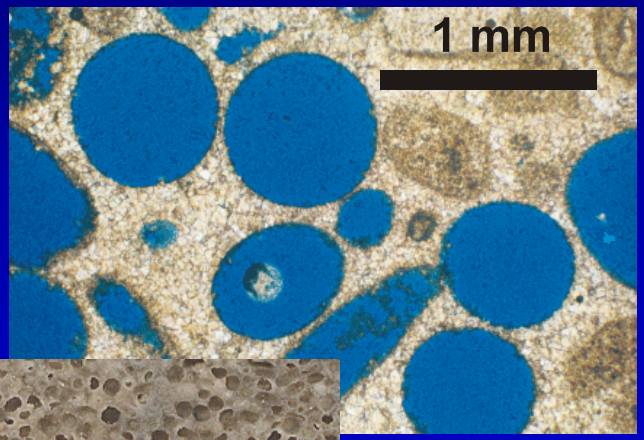


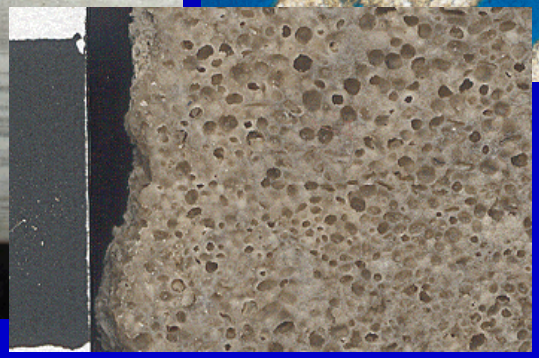
1 ton CO_2 = 17.23 mcf

Dubois, White and Carr, 2002

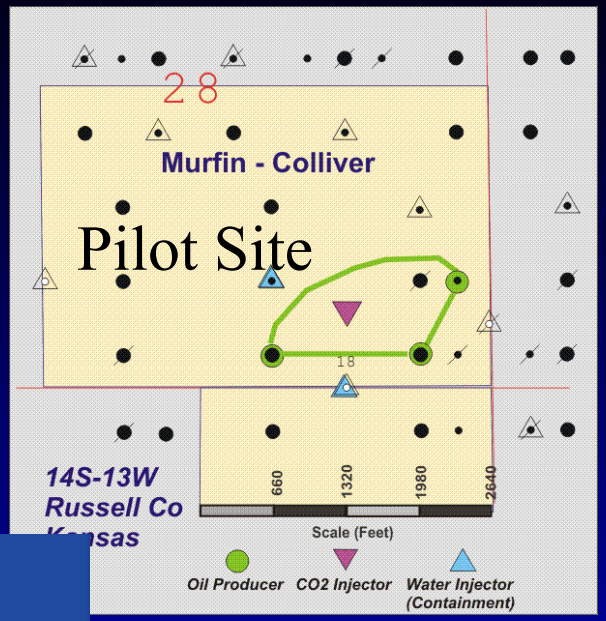
The CO_2 EOR Oil Resource

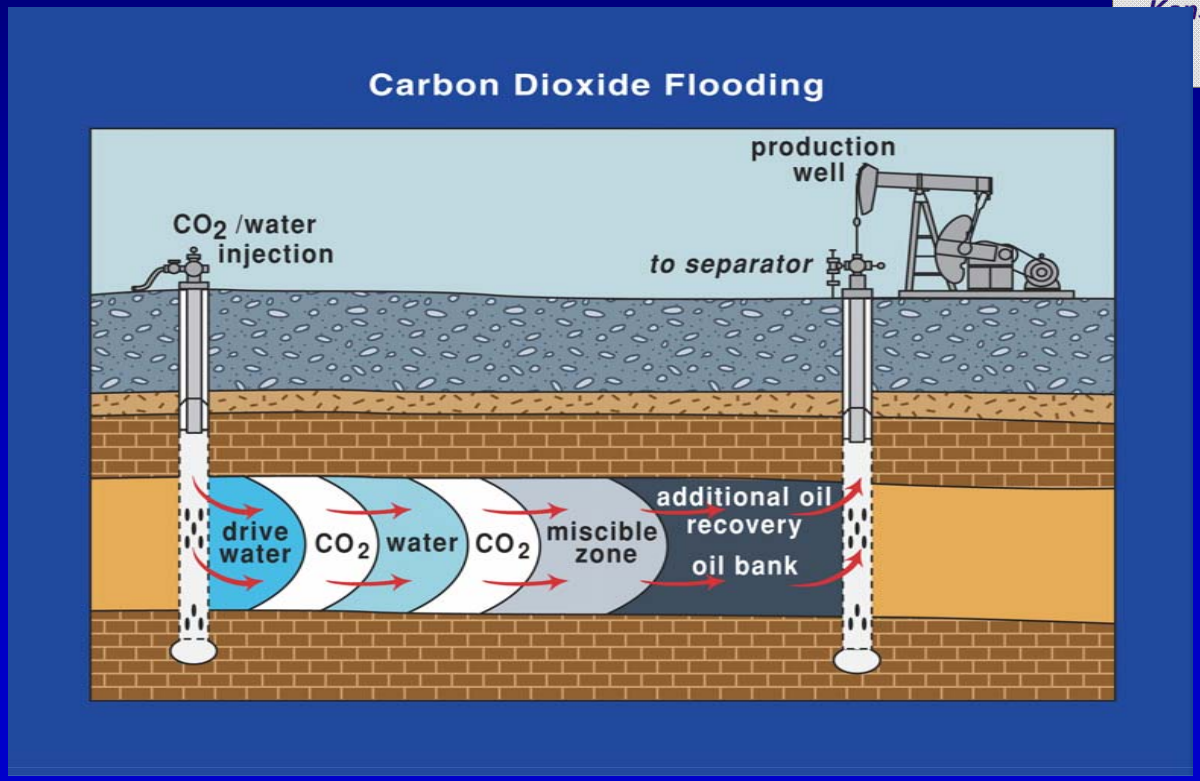
Sorw	30%
Porosity	30%
Perm.	100 md

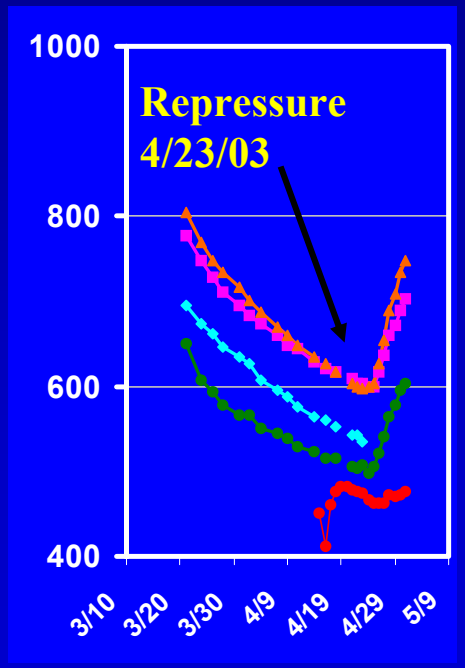




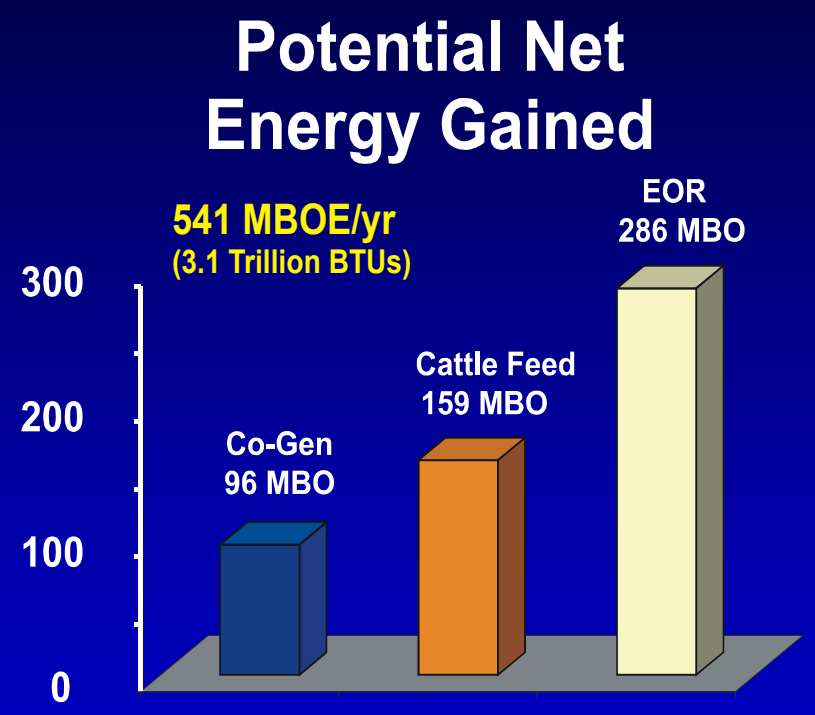
DOE Funded EOR Project

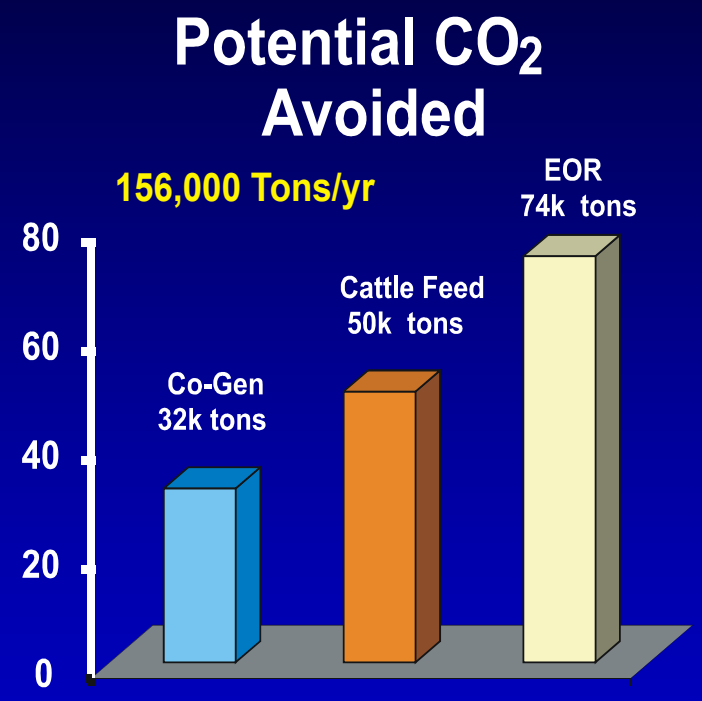






Potential Energy Gain and CO_2 Avoided





Model Assumptions:

- All systems are run at full capacity (ethanol plant, co-generation, CO_2 EOR)
- Entire CO_2 stream is used for CO_2 EOR
- Net utilization = CO_2 sequestered = 4.3 mcf (0.25 ton)/BO recovered
- Distillers Dried Grains (DDG) are fully utilized and offset cattle grain feed

Gains are calculated by comparison with same systems operating independently (without waste product utilization).

(Combustion of 1 BO yields 7 mcf CO2. Average EOR CO_2 net utilization is 5 mcf /BO.)

Principle Economic Factors

Pipeline Company

1) Capital costs
   - **Dehydration & compression**
   - **Pipeline (distance)**
2) Operating costs
3) **Raw CO_2 costs**

Determines CO_2 Price

Oil Operator

1) **CO_2 costs**
2) Oil price
3) Capital costs
4) Operating costs
5) CO_2 EOR efficiency risk
   - **Net and Gross utilization rate**
   - **Resource base**

"Economies of Scale"

Economic Summary for CO_2 Aspects of Linked Systems

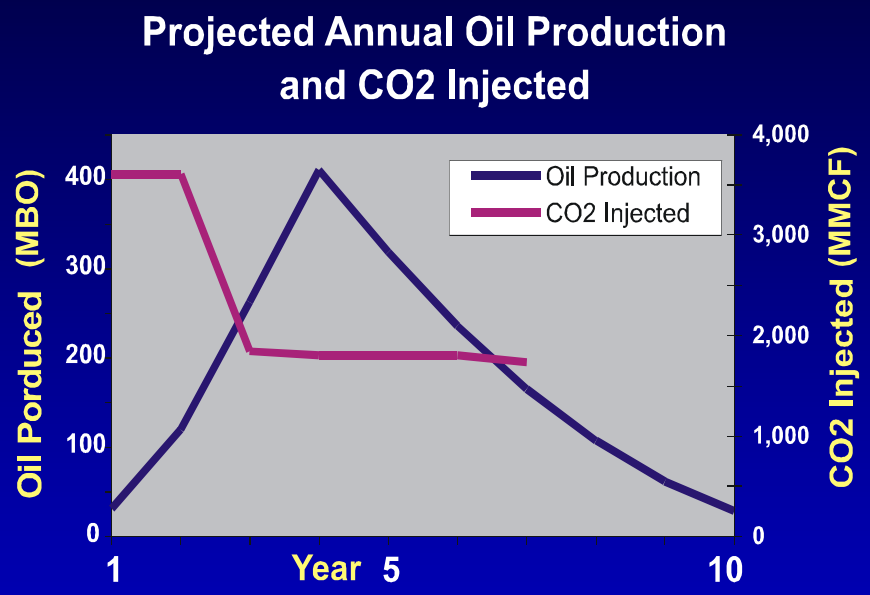
	EOR Oil Operator	Pipeline Company	Ethanol Plant
Capital Costs	$4,094,806	$1,400,000	$0
Rate of Return	**19.5%**	**21.3%**	**NA**
NPV	$3,121,080	$845,553	$3,105,882
Profit (BT)	$8,724,656	$2,084,394	$4,819,356

Barrels Oil 1,712,687

CO_2 Sales 12.8 BCF (743 k tons)

Assumptions: Entire CO2 stream from a 25 million gal/yr ethanol plant is delivered by 4" pipeline for EOR and CO_2 net utilization = 4.4 mcf/BO for ten years.

Economics for CO_2 EOR



Model: Small commercial flood using entire ethanol plant CO_2 stream delivered at $1.00/mcf ($17/ton).

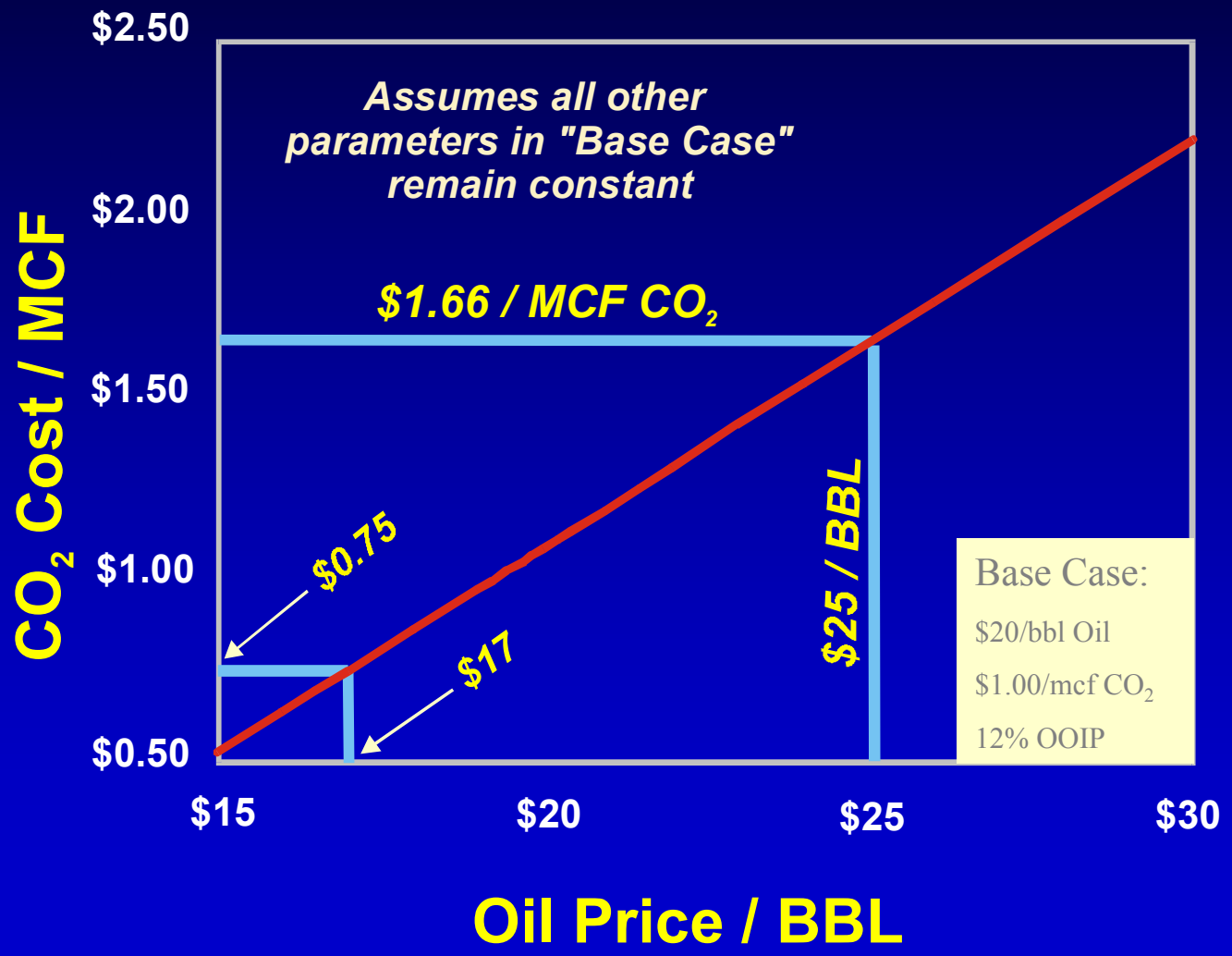
Critical Assumptions

Oil Price	**$20/BO**
Purhased CO2 Cost	**$1/MCF ($17/ ton)**
Recycle CO2 Cost	**$0.35/MCF**
Gross CO2 Utilization	**9.5 MCF/BO**
Net CO2 Utilization	**4.4 MCF/BO**

Economic Measures

Rate of Return	**19.5%**
(10% discount) NPV	$3,121,080
Profit (BT)	$8,724,656
Profit(BT)/Capital	213%
Net Ultimate Rec (BO)	1,498,601
Gross Ultimate Rec (BO)	1,712,687

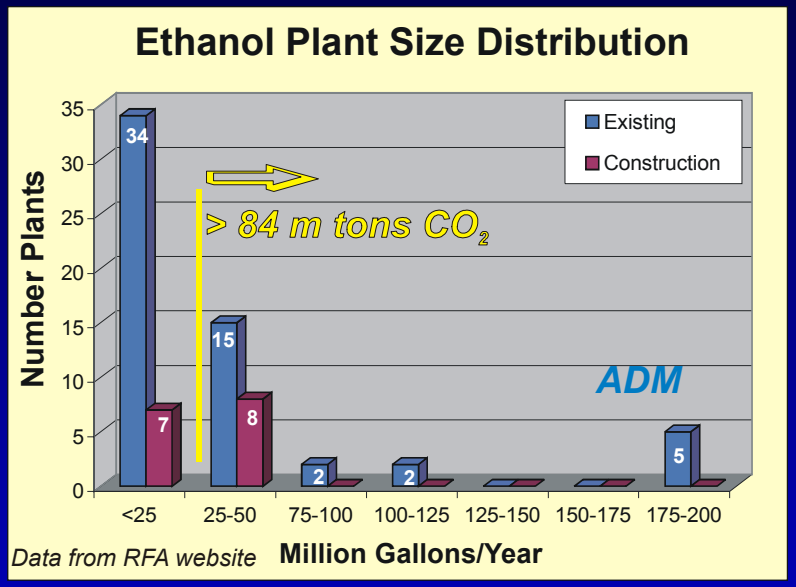
CO_2 Costs vs. Oil Price for 20 % IRR



Dubois, Byrnes, Pancake, etal, OGJ (2000)

Scalability of the "Russell Model"

- Minimum CO_2 volume required by economics dictates 25 million gallon/yr ethanol plant
- EOR resource base could support 10–20 times that volume
- Kansas agribusiness (grain & cattle) could support much larger ethanol market

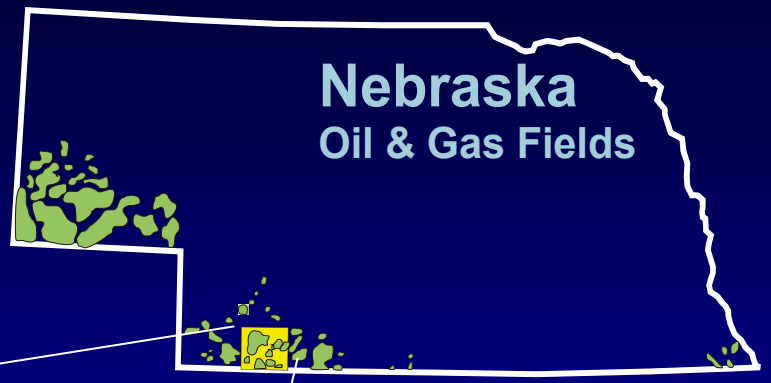


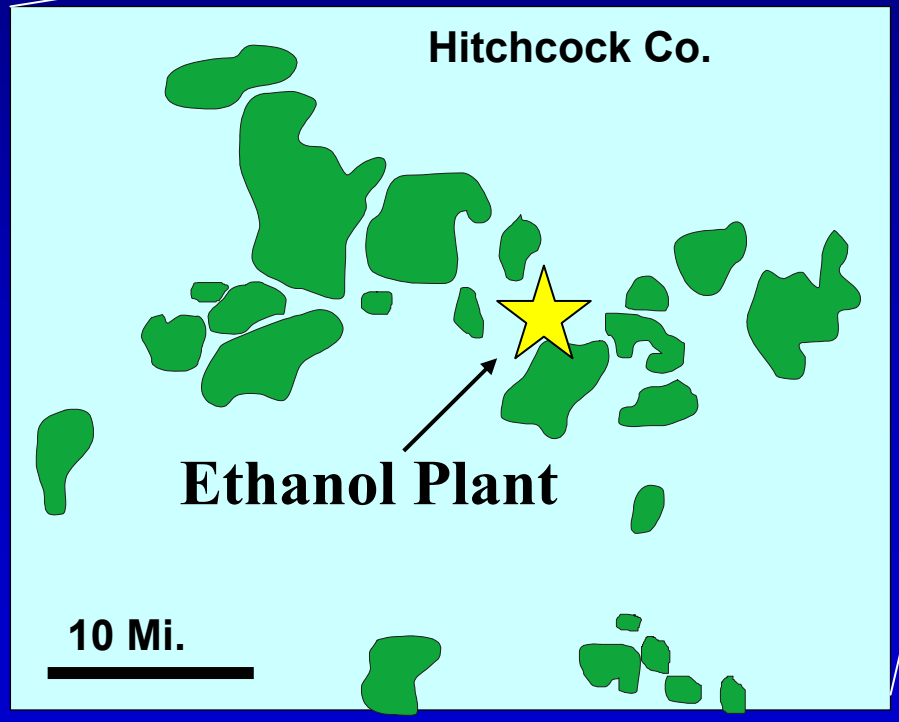
Ethanol plant constraints:

Feedstocks	Water
Energy	Transportation
Ethanol market	DDG markets

Maximum economic transport distance is a direct function of volume (plant size)

New Ethanol Plant in SW Nebraska Oil Fields



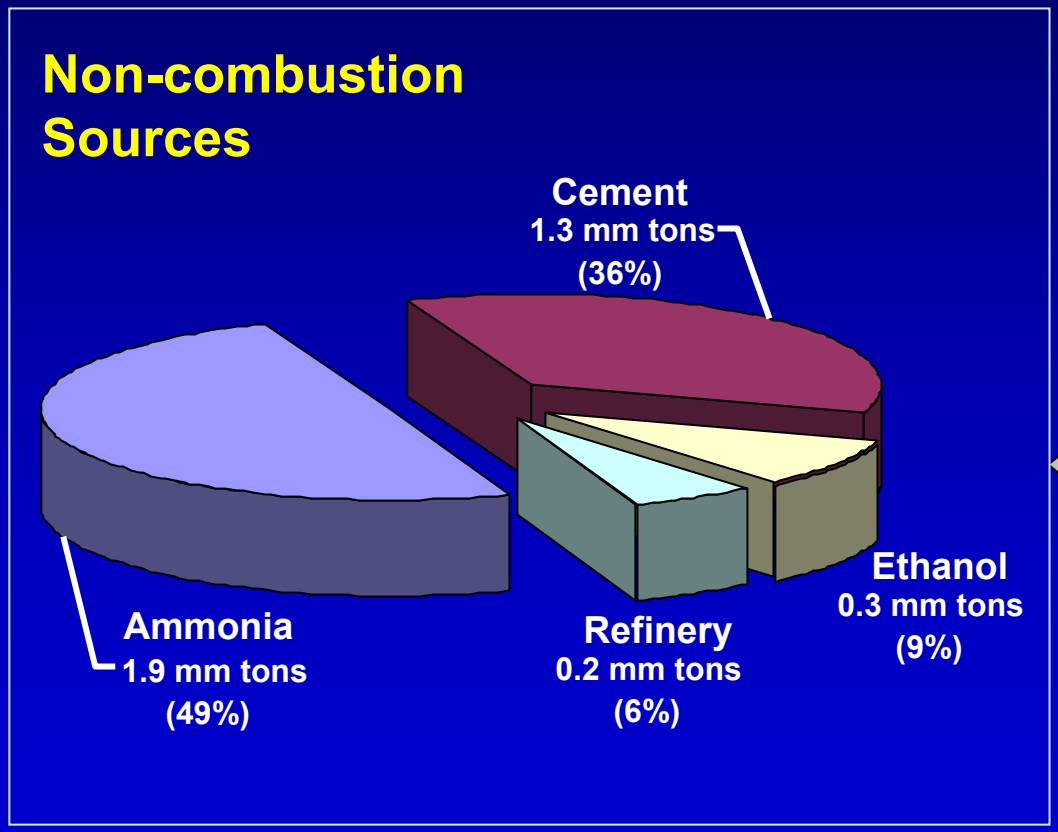


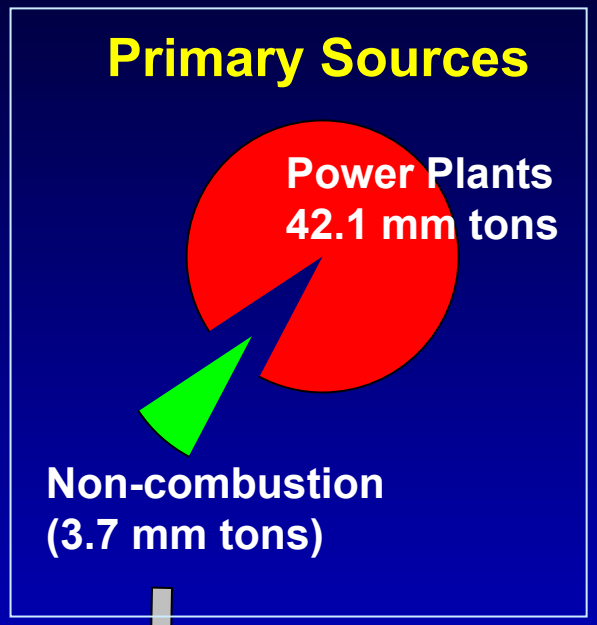
Trenton Agri Products LLC

Construction mid-2003
Operation mid-2004

30-40 Million gal/year
90-120 k tons CO_2/year

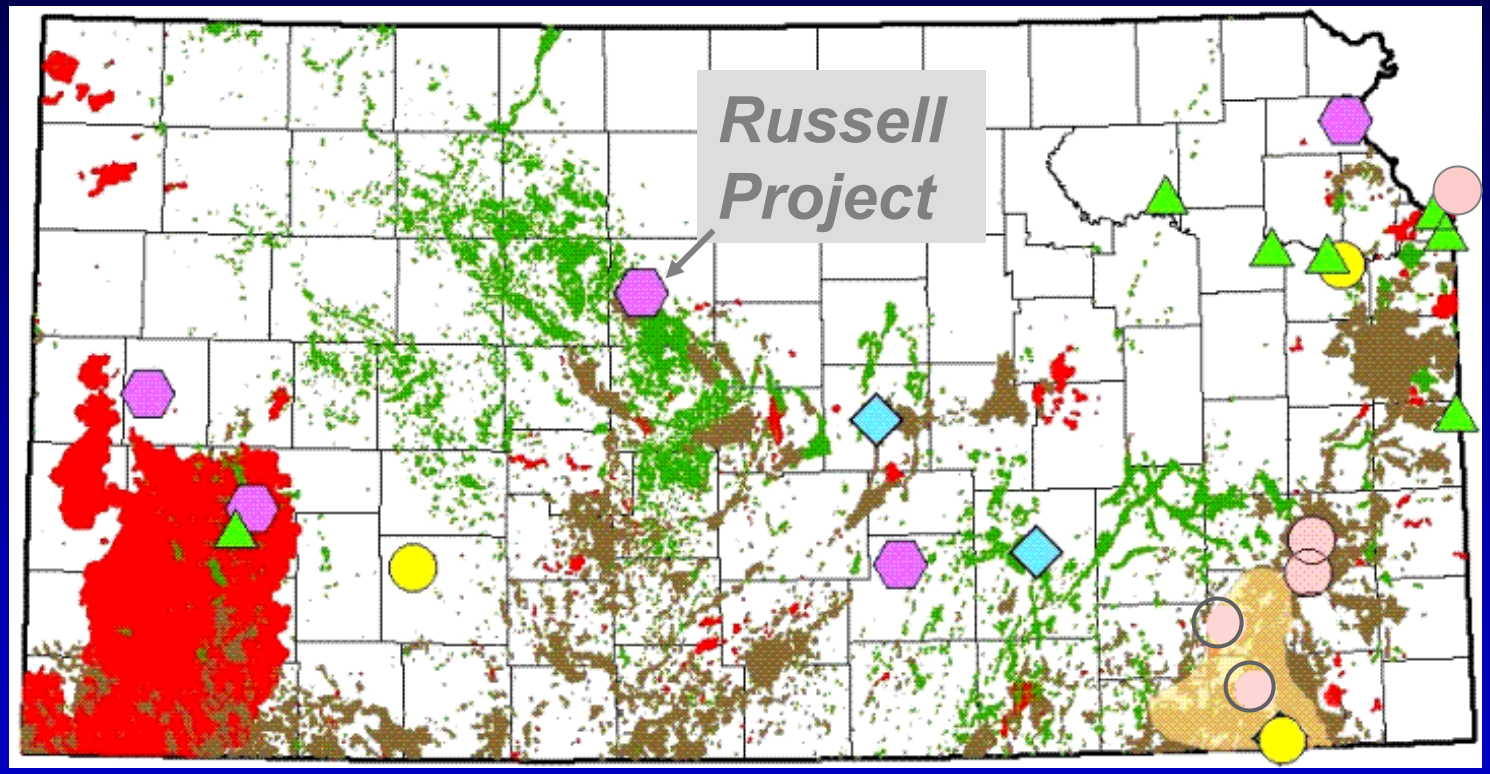
Candidate Kansas Sources for CO_2 Capture





Annual CO_2 Emissions

Kansas Industrial CO_2 Sources



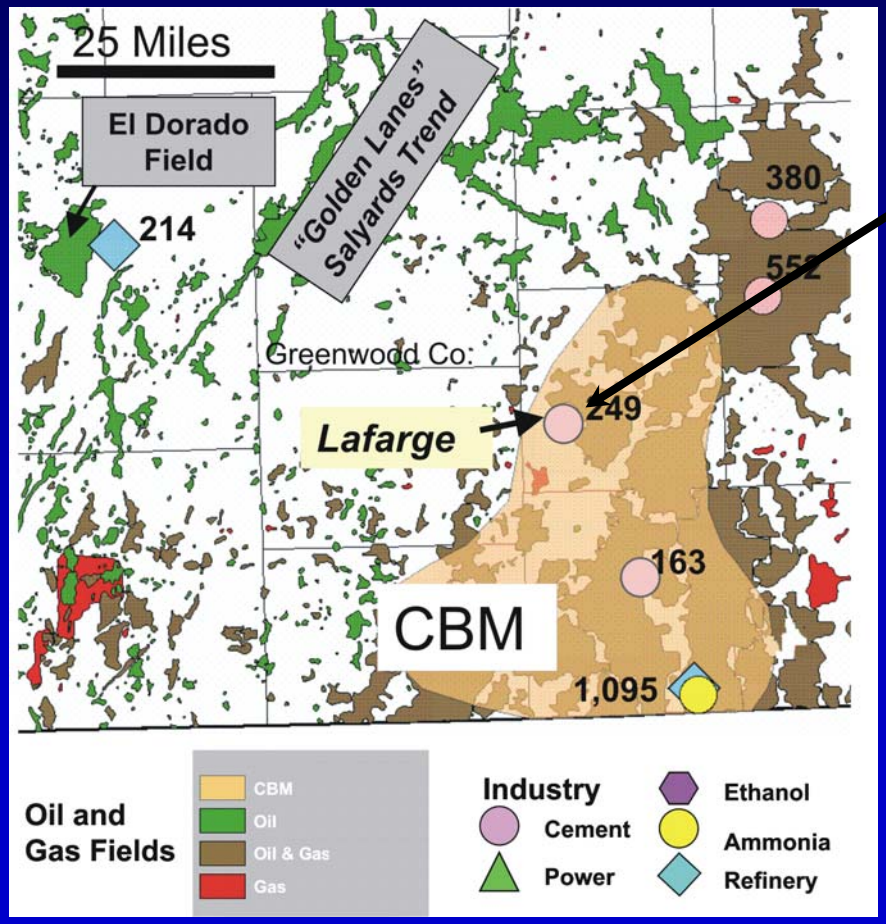
Oil and Gas Fields

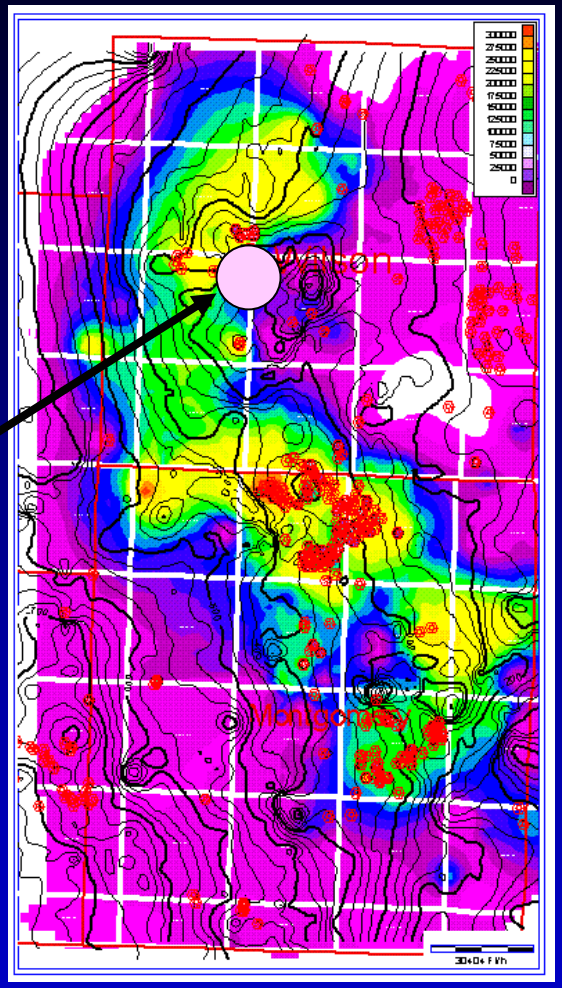
- CBM
- Oil
- Oil & Gas
- Gas

Industry

- Cement
- Power
- Ethanol
- Ammonia
- Refinery

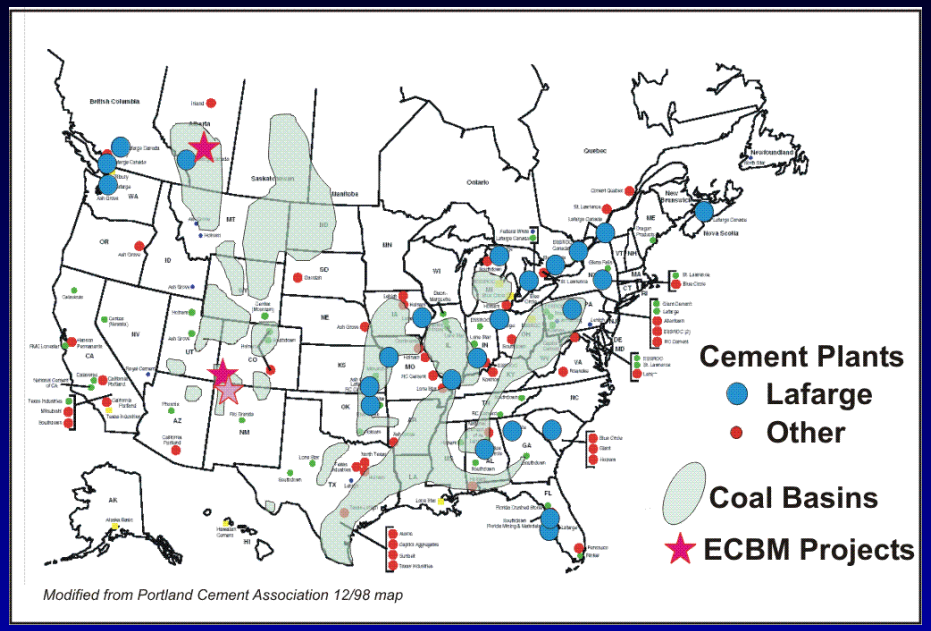
Enhanced Coalbed Methane with Cement Plant Gases





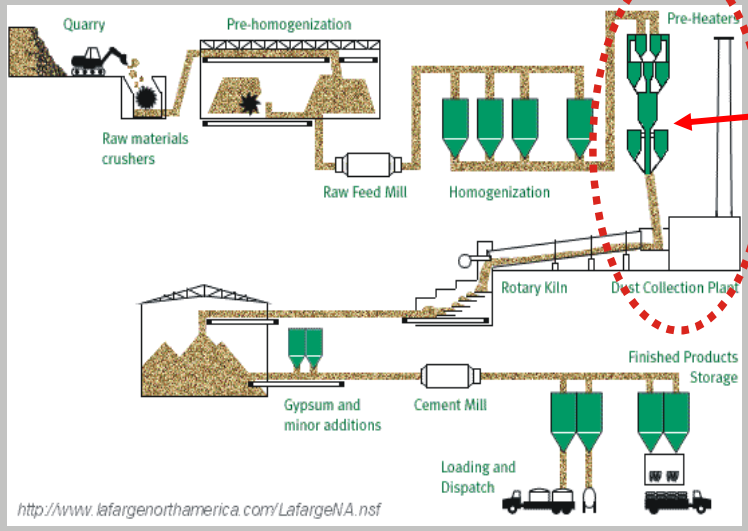
Weir-Pitt coal, Wilson and Montgomery Counties
(Jonathan Lange, Kansas Geological Survey)

Cement Plants and Coal Basins in U.S.



Modified from Portland Cement Association 12/98 map

Dry Kiln Portland Cement Process



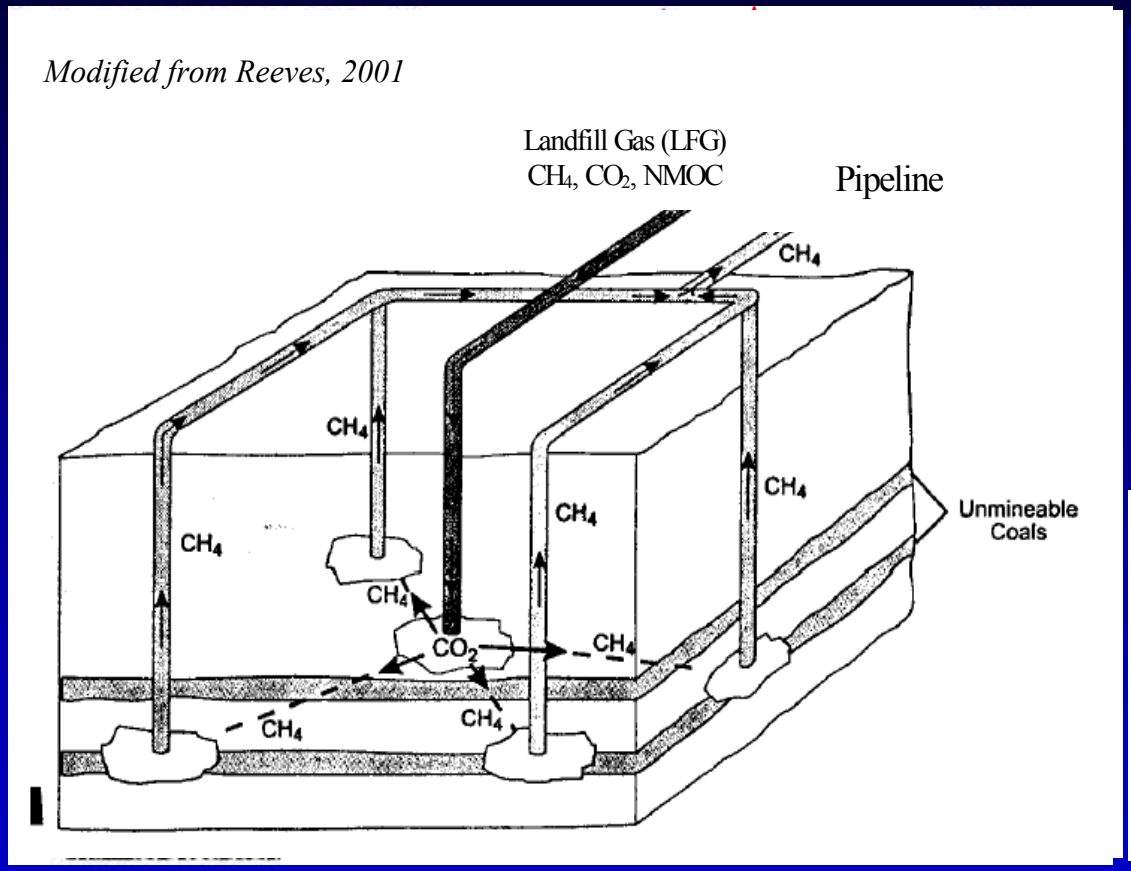
Calcination Process

$CaCO_3 > CaO + CO_2$

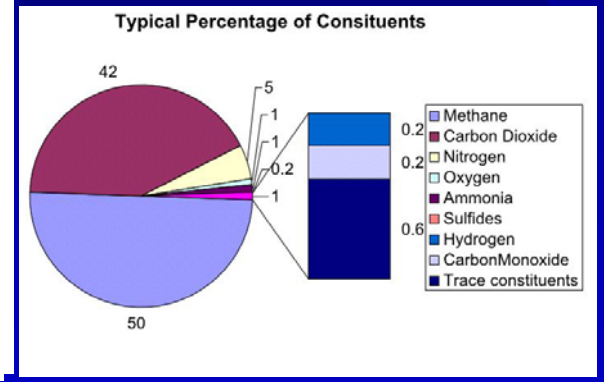
0.51 tons CO2 / ton cement

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

Landfill Gas and ECBM



Integrated landfill gas generation and processing coupled with ECBM & CO_2 sequestration



Potential for processing 50-50 methane/CO_2 mix from landfills through coalbeds for ECBM while economically processing landfill gas.

Linked Systems Make Sense

- Linked energy systems like the Russell model make economic and environmental sense at present scale
- Russell model is scalable (upward) and there do not appear to be ethanol production related constraints for expanding size
- Potential for ethanol CO2 and EOR linkage likely to be realized in mid-continent region fairly soon
- Potential linkage of other systems with high purity and less concentrated CO_2 should be seriously considered

Similar paper available online

http://www.kgs.ku.edu/PRS/Poster/2002/2002-6/index.html