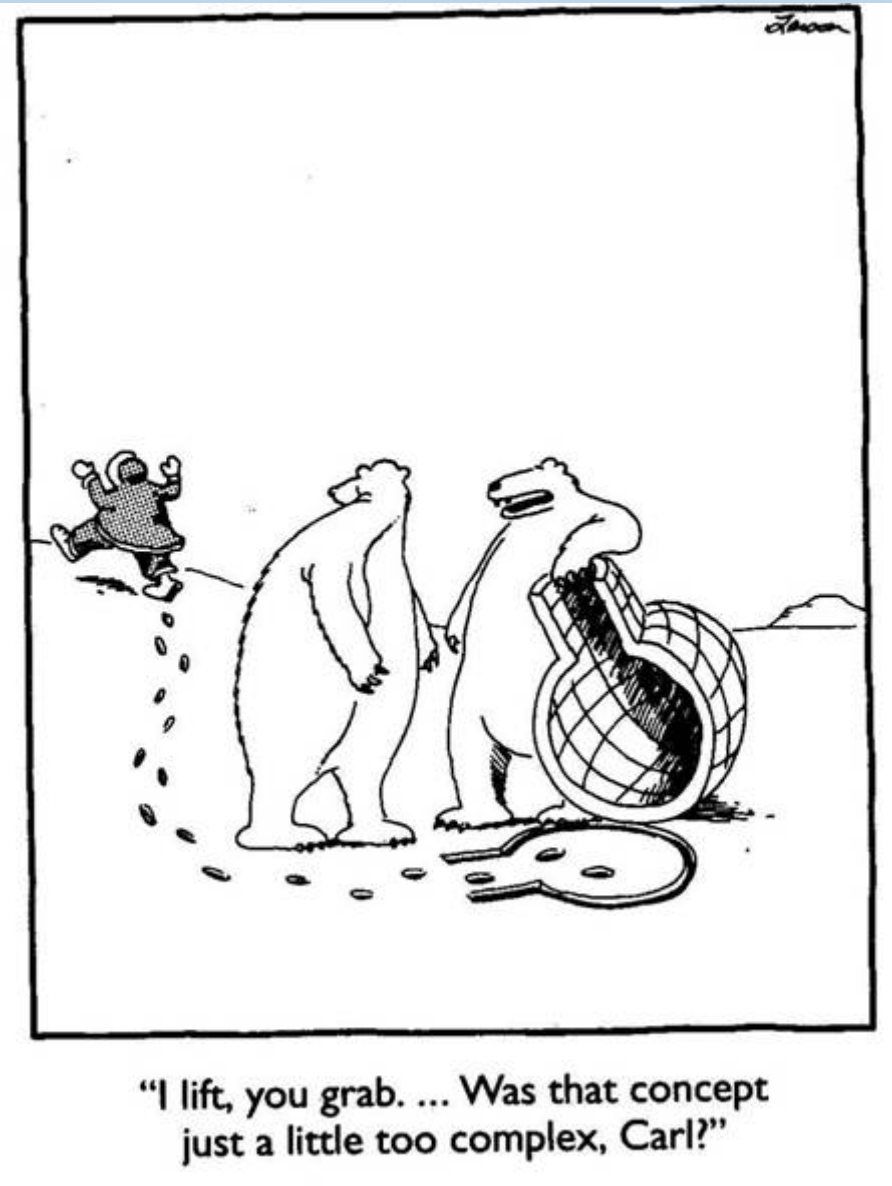
Using Industrial Sources of CO_2 for Value-Added Geologic Sequestration

Challenges & Approaches

Timothy R. Carr
KU Energy Research Center
Kansas Geological Survey
University of Kansas

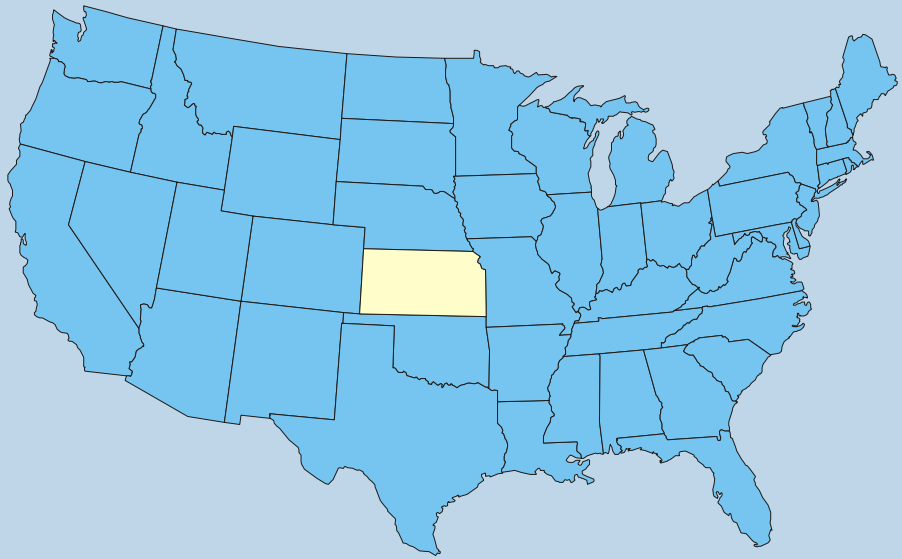


"I lift, you grab. ... Was that concept just a little too complex, Carl?"

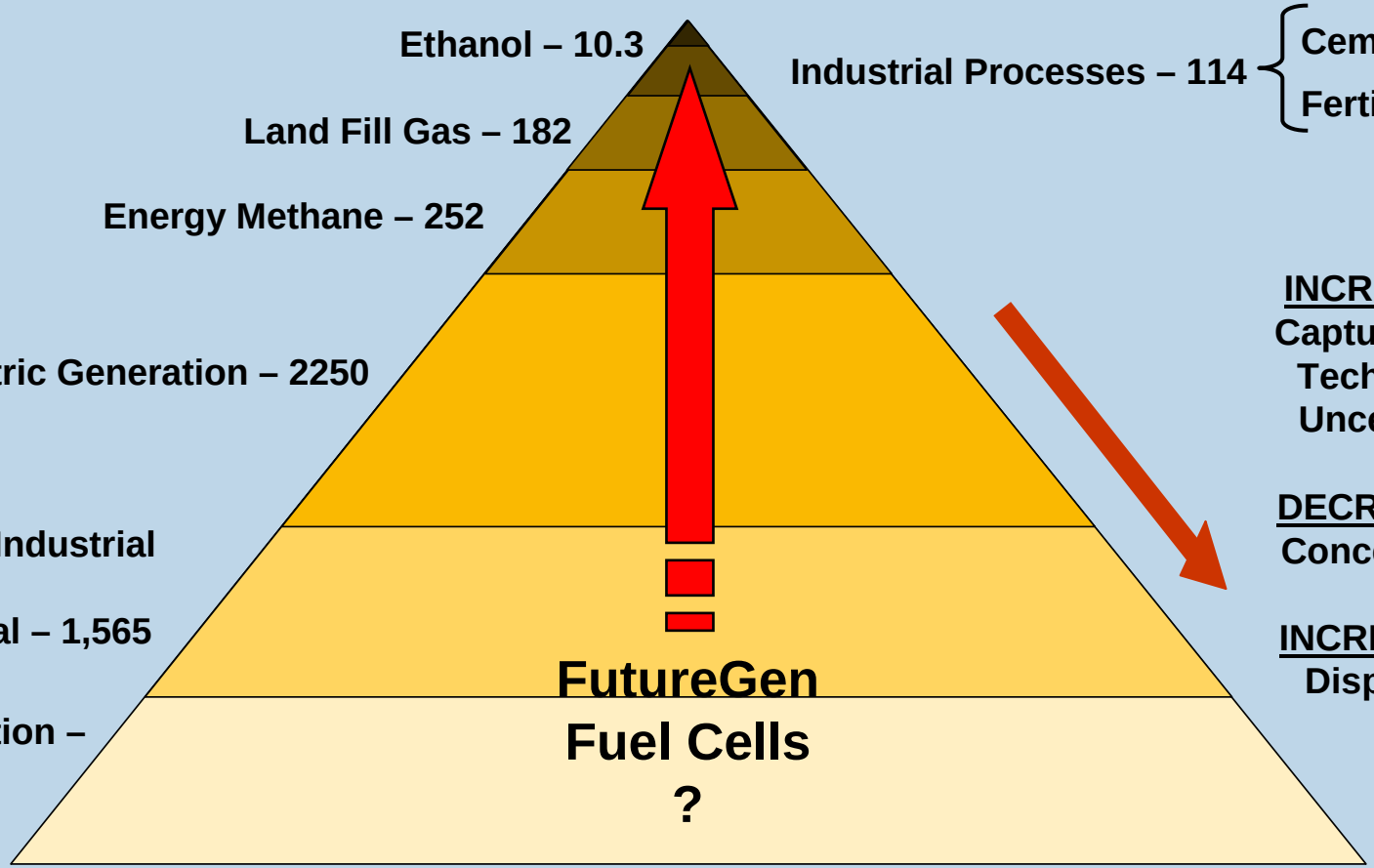
Perhaps integration of energy systems represents too many complexities for standard business approaches and regulatory regimes

Kansas Approach

- Inventory & Evaluate Greenhouse Gas Resources
  - Multiple Scales (Nation – Regional – Local – Single Source
- Inventory & Evaluate Sequestration Opportunities
  - Multiple Scales (Nation – Regional – Local – Wellbore
- Guiding Principles
  - Economically Viable
  - Environmentally Sound
- Integrated Energy Systems
  - Ethanol Plants
  - Landfills
  - Cement Kilns
  - Fertilizer Plants
- Viewing CO_2 as a Resource
  - Path to the Future ⇒ IGCC ⇒ Carbon Management



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 6,873 Million Metric Tons

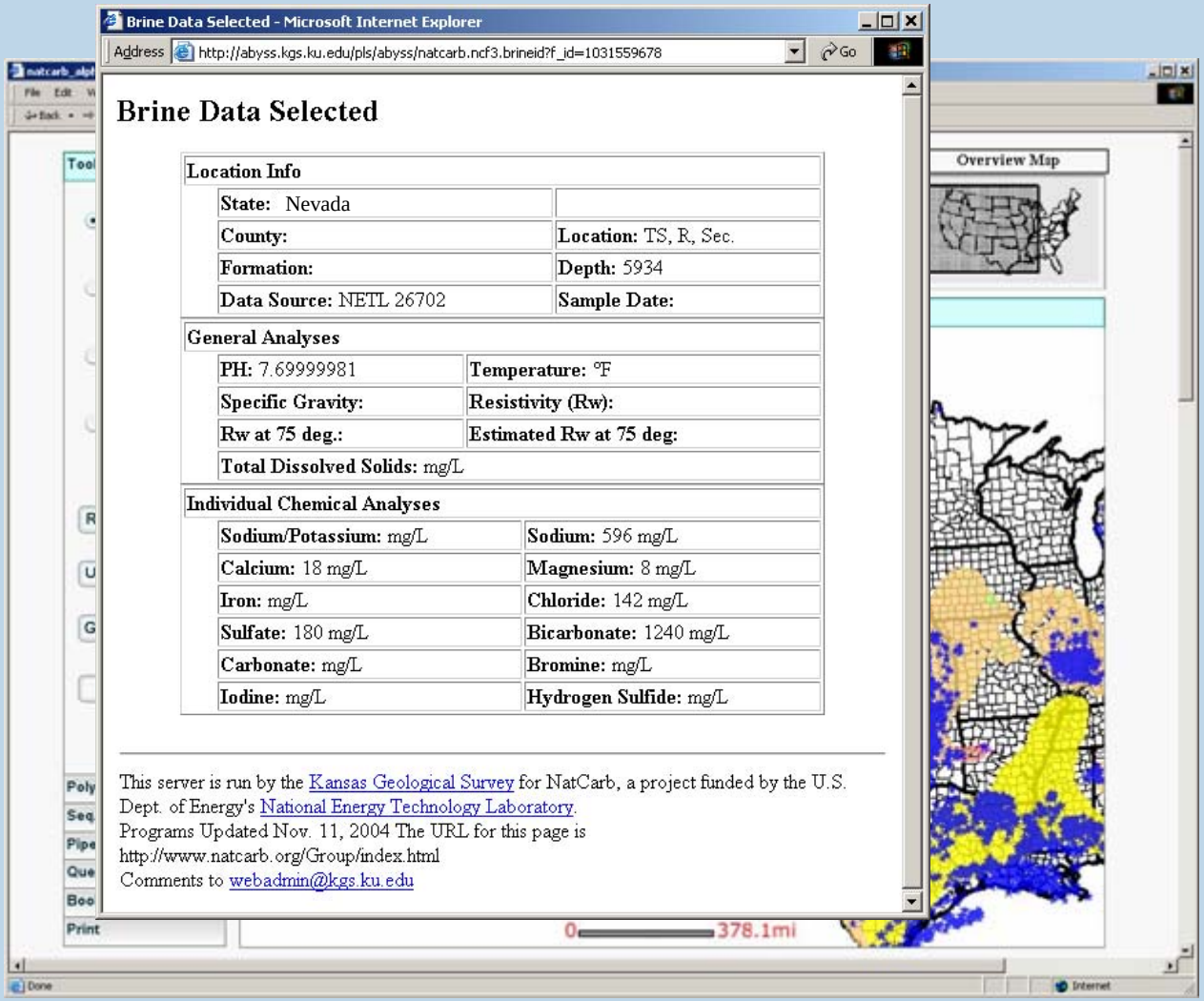
Data: Year 2002 Energy Information Agency and Renewable Fuels Assos.

NatCarb – Inventory & Evaluate

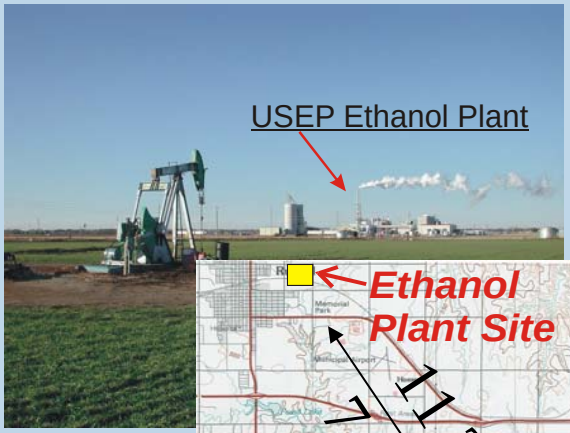
Carbon Resources

NatCarb – Inventory & Evaluate

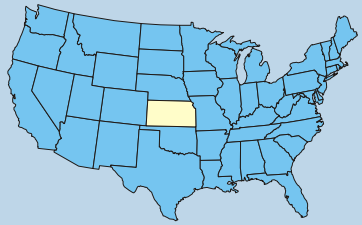
Sequestration Opportunities

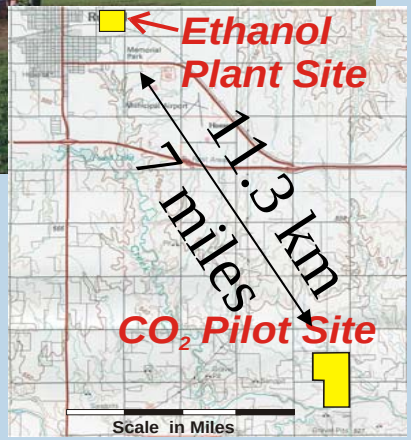


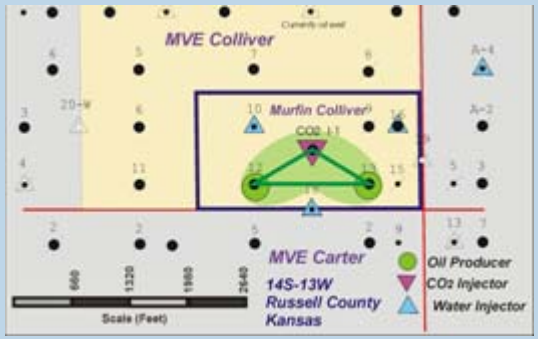
Russell, Kansas Project

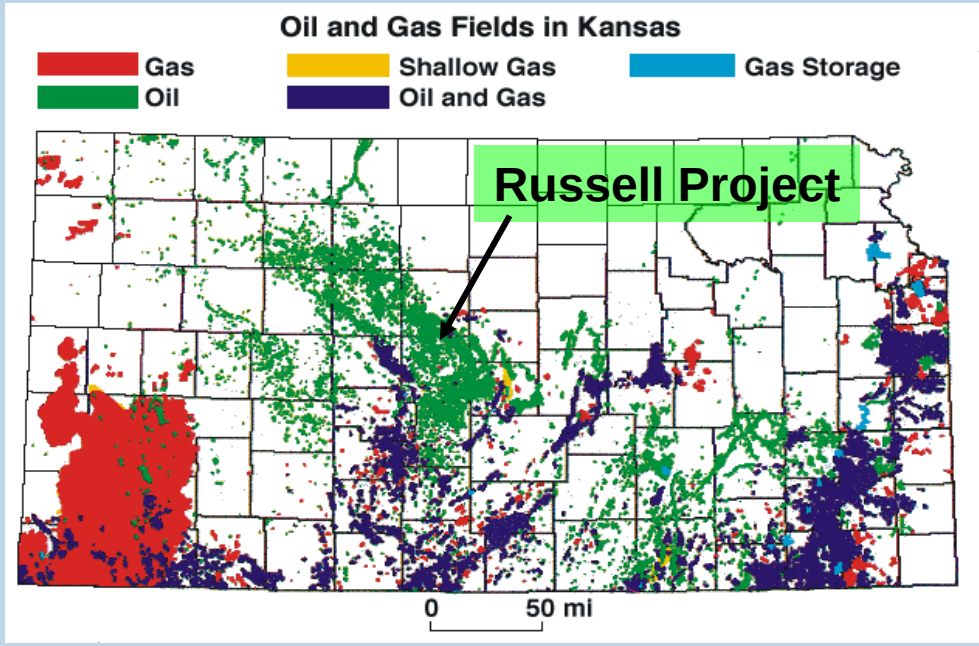


First Sequestration
of Agricultural CO_2





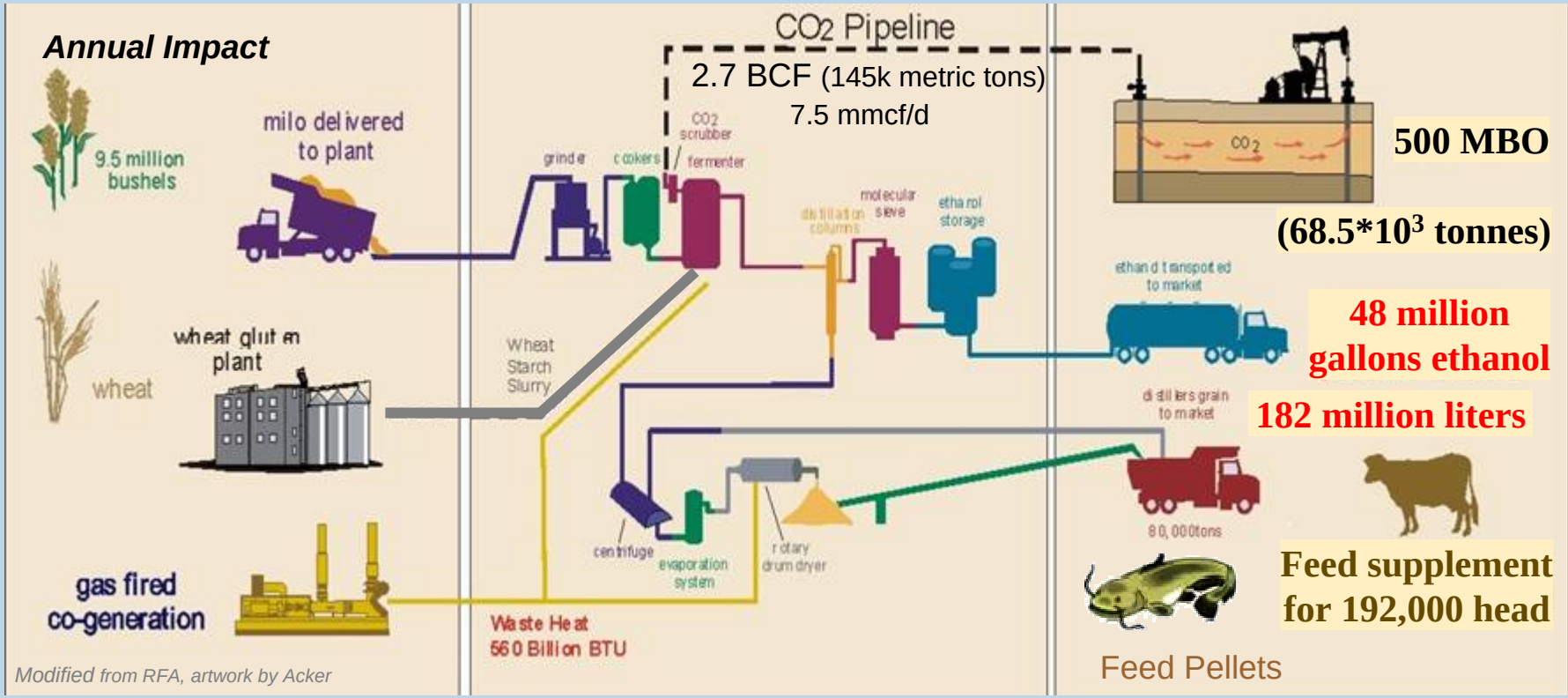




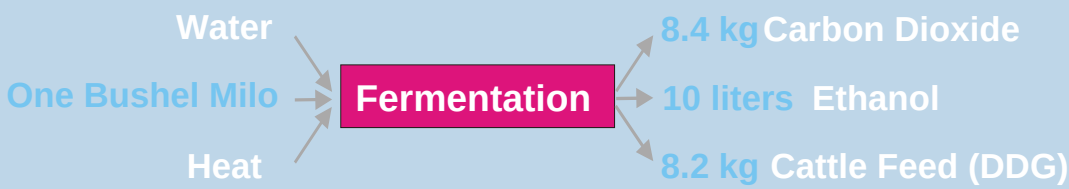
Russell is centered in oil,
grain and cattle region

Integrated Energy Systems

Raw Materials — Ethanol Plant — Products

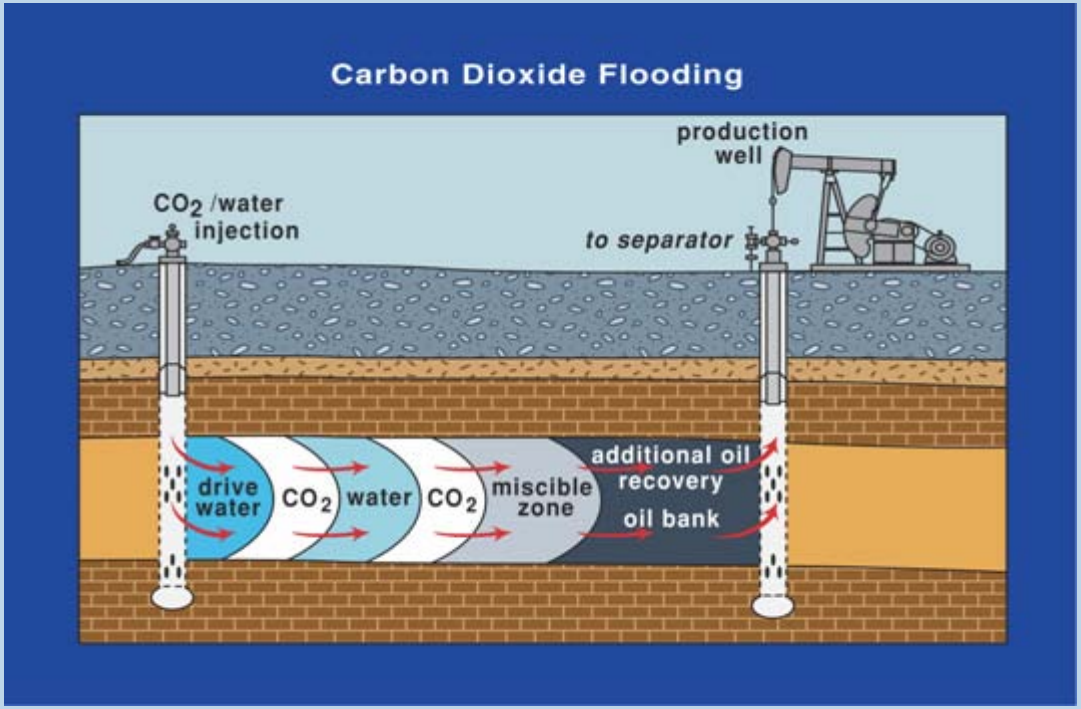


1 metric ton CO_2 = 19 mcf



CO2 Miscible Flood Demonstration

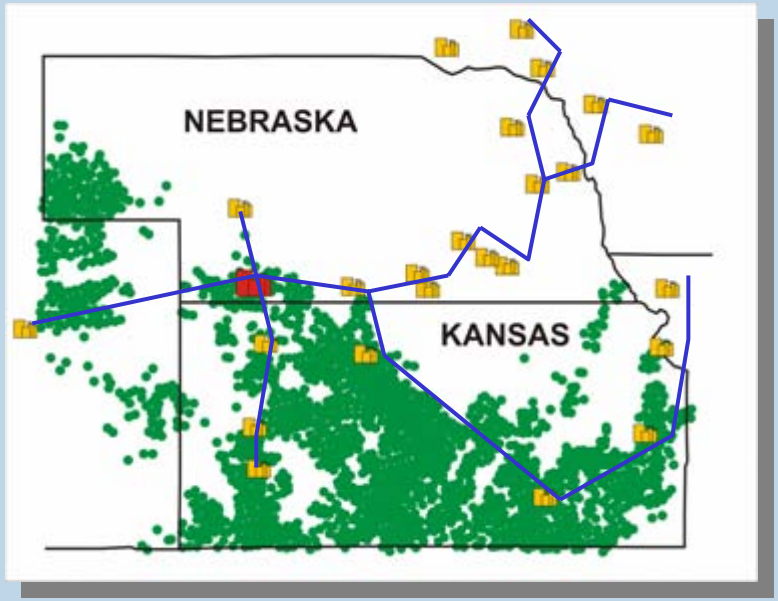
- 10+ acre, three-spot
- 1 CO_2 injector
- 2 Producers
- 1 Monitoring
- 2 Containment Water Injectors
- 0.29 BCF (15,263 tonnes) CO_2 Injected-WAG
- 6 year operating life
- 18,000 BO (2466 tonnes) estimated recovery

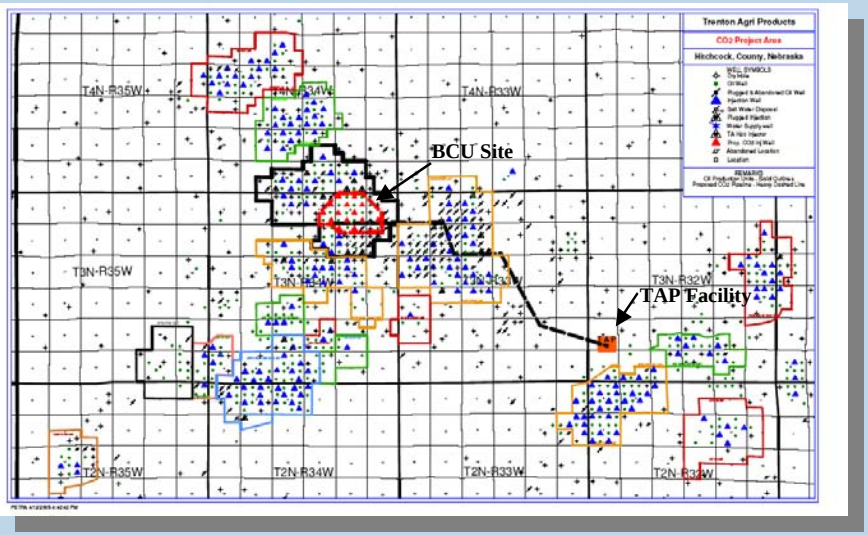


www.kgs.ku.edu/ERC/CO2Pilot

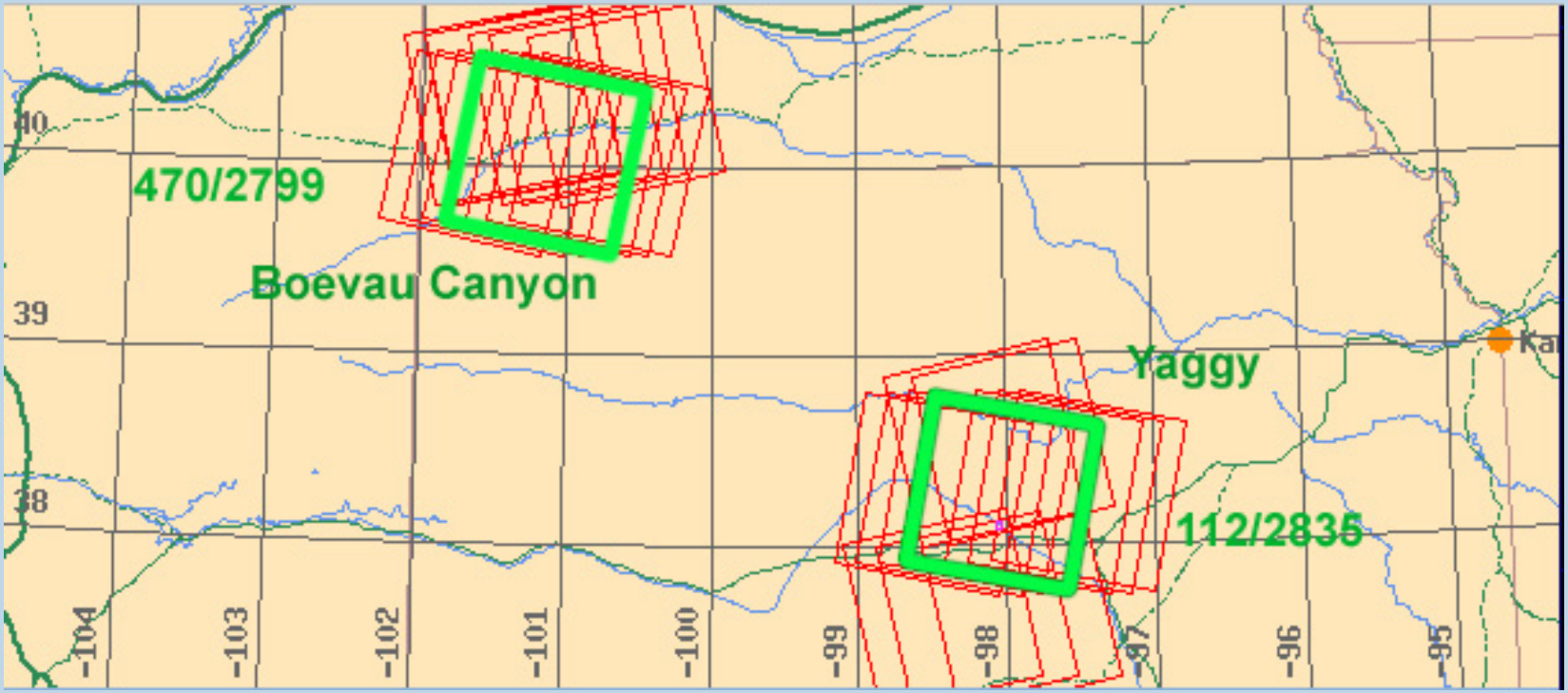
Boevau Canyon, NE
Field-Scale Demonstration

- 14 CO2 injection Wells - 16 Producers
- Ethanol 36 → 45 MGY (136 → 170 M liters)
  - Corn & Milo 17 Million Bushels
    - (432 Million kg)
  - 137 metric tons (Mt) DDG
    - 172,000 Head of Cattle
- 300 → 375 Mt/day (5.6 → 7.0 mmcf/d)
- Verification and Carbon Credits



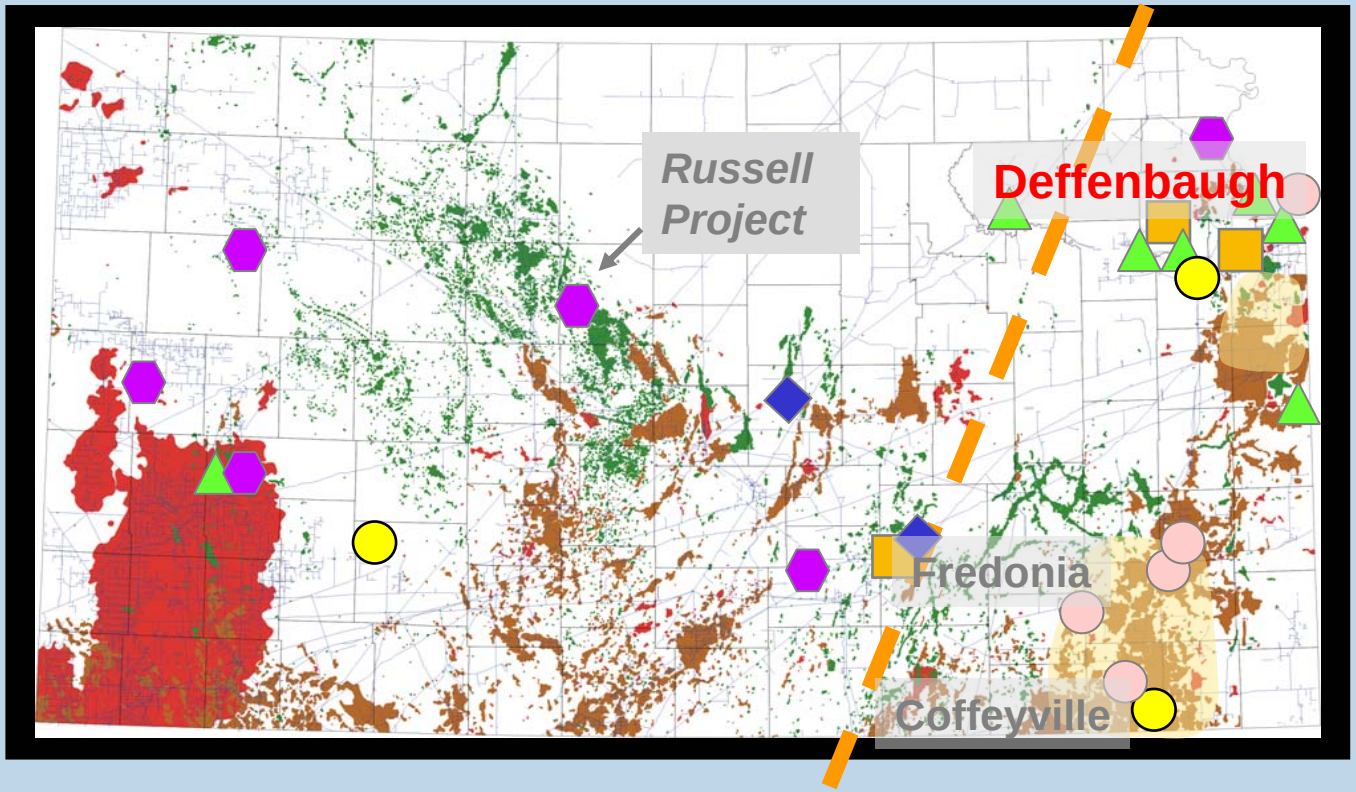


Boevau Canyon, NE – MMV



- **InSAR Coverage**
  - Coverage, 1992 to present
  - Green Frame shows areas with >20 scenes
  - Monitor mm-scale deformation

Major Kansas GHG Sources



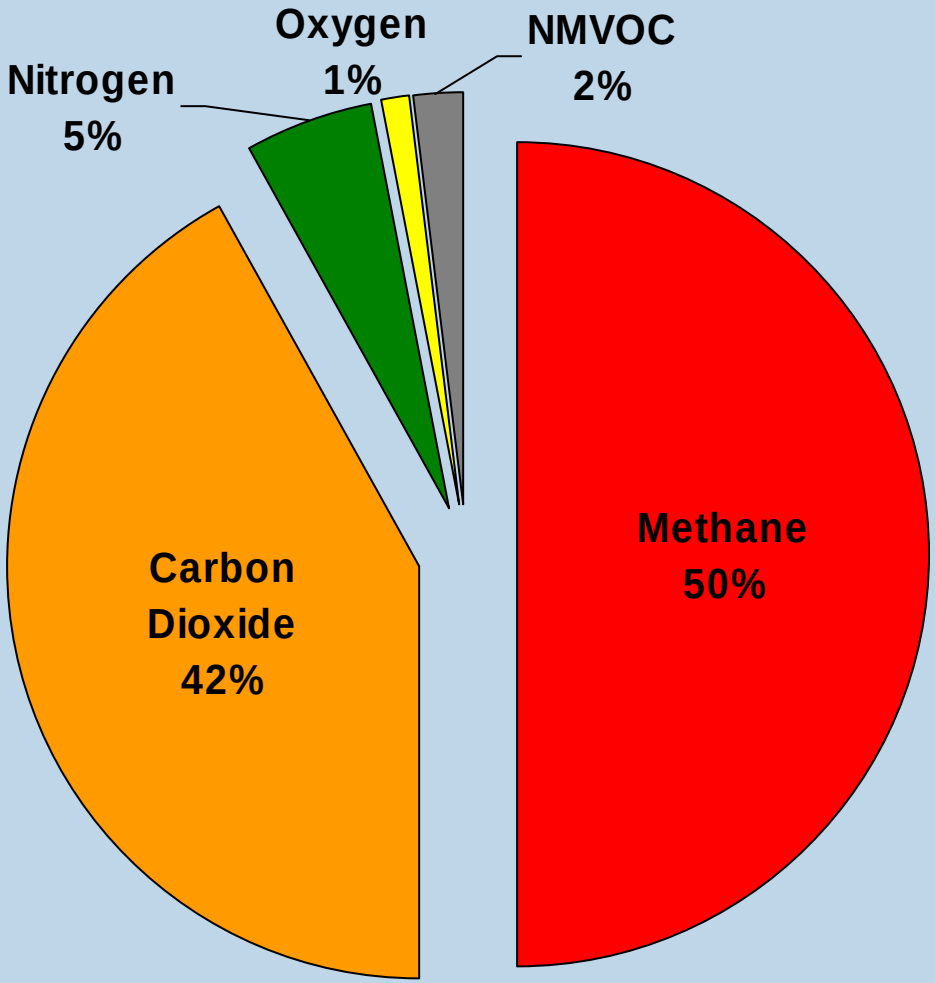
Oil and Gas Fields

- CBM
- Oil
- Oil & Gas
- Gas

Industry

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

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
- **subsidy $1.09 mcf ($0.04 m^3)**

Capture Costs

- **12-15 Cents/Kwh (3600 kJ)**
  Assuming 33% efficiency

Deffenbaugh Facility

- **LFG 4.5 mmcf/day (236t/d)**
  CO_2 equiv.
  54 mmcf (2842 t/d)
- **CH_4 sold 1.8 mmcf/d (95t/d)**
- **116 tonnes CO_2 and NMVOC vented per day**

Deffenbaugh Facility

- 18 Mt of Waste in Place
- Additional 1.5 Mt per Year Received
- LFG 4.5 mmcf/day (236t/d)
  - 150 Wells
  - Gathering System
    - 7 miles of 22” pipe under 45” of water vacuum
- CO_2 (GHG equiv.) 54 mmcf/d (2842 t/d)
- CH_4 recovery 2.5 mmcf/d (132 t/d)
- CH_4 sold 1.8 mmcf/d (95t/d)
- 116 tonnes CO_2 and NMVOC vented per day

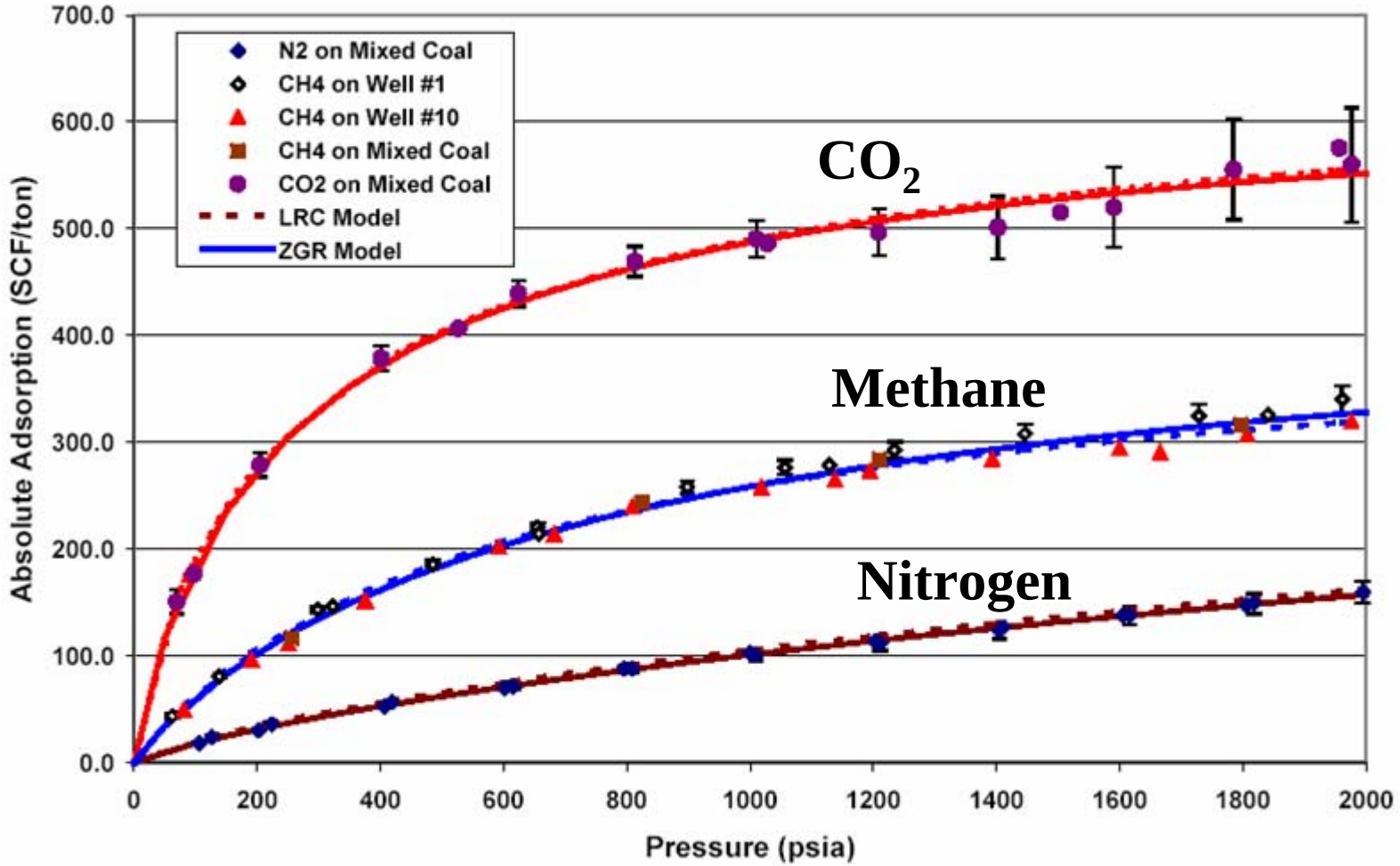
Trash Cell (ready to take waste)

Landfill Gas Well

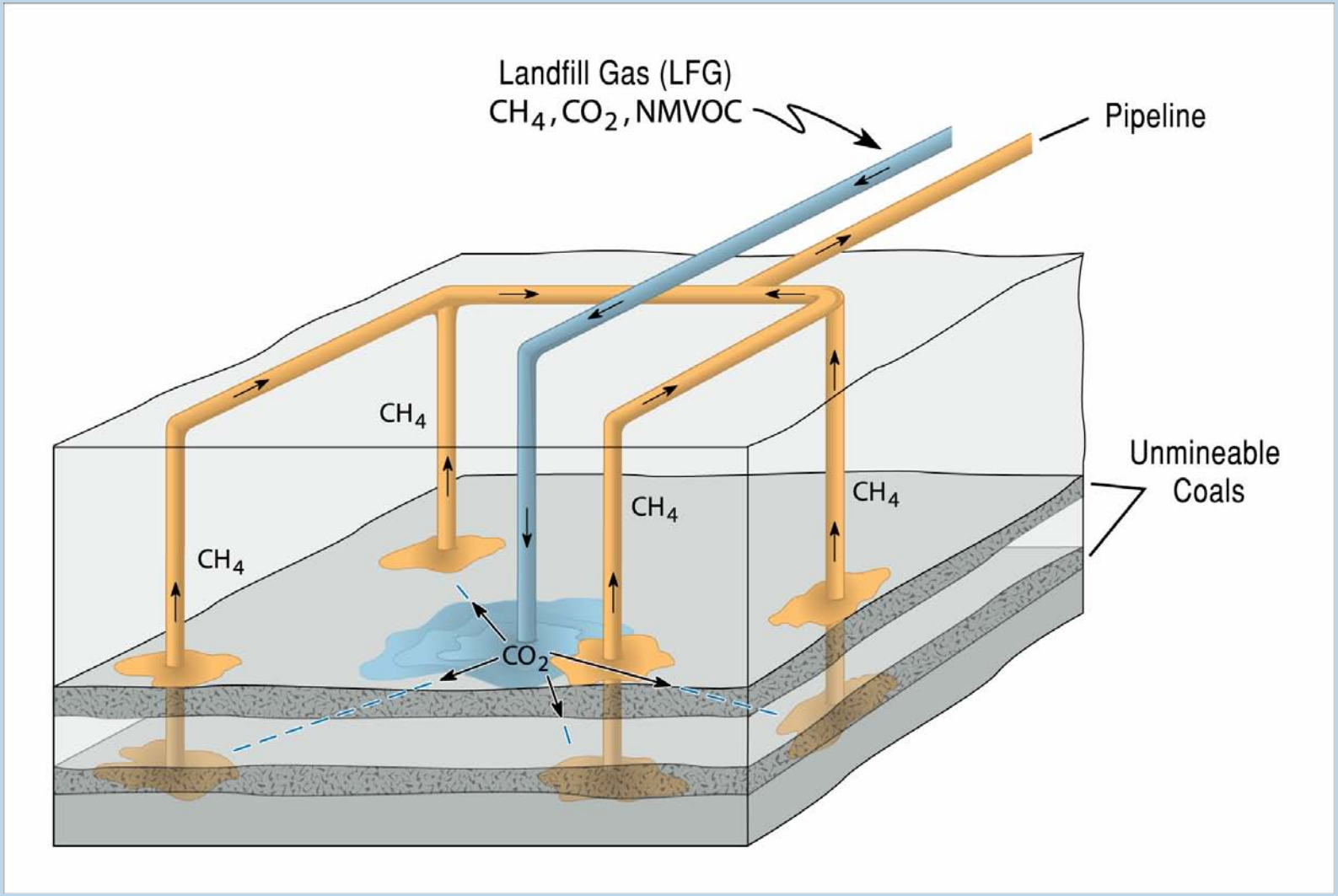
Landfill Panorama (showing gas plant & drill rig)

Landfill Gas

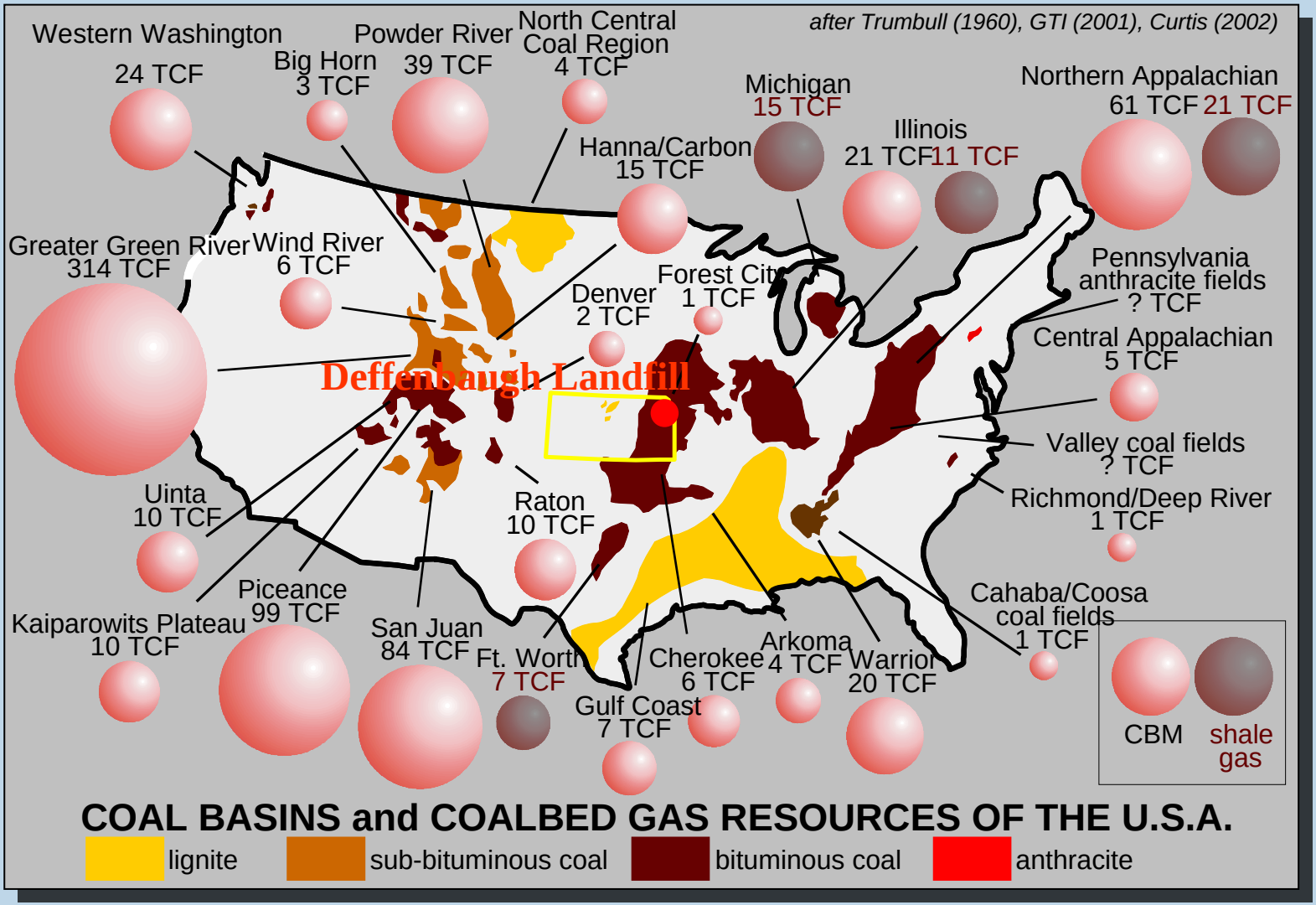
Adsorption Isotherms



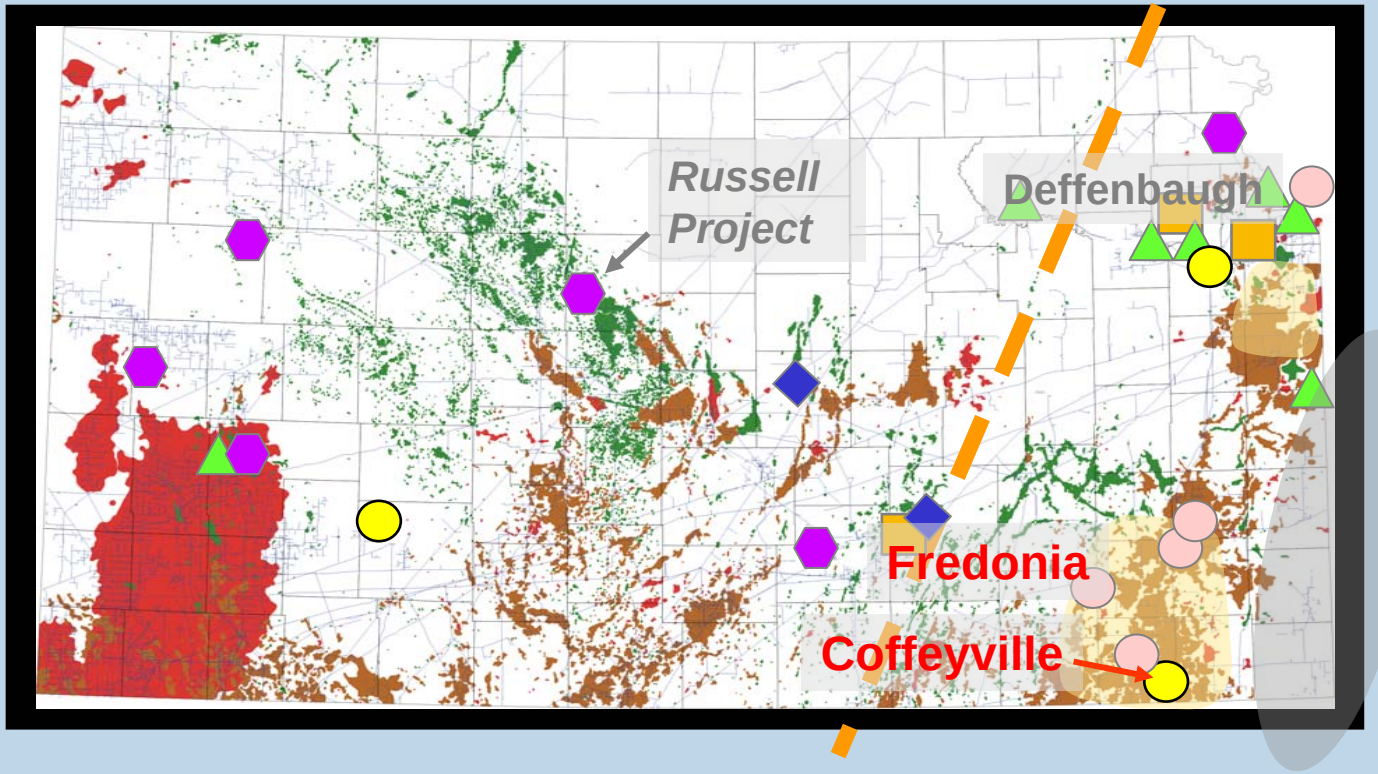
Landfill Gas



Landfill Gas & CBM Basins



Major Kansas GHG Sources



Oil and Gas Fields

- CBM
- Oil
- Oil & Gas
- Gas

Industry

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

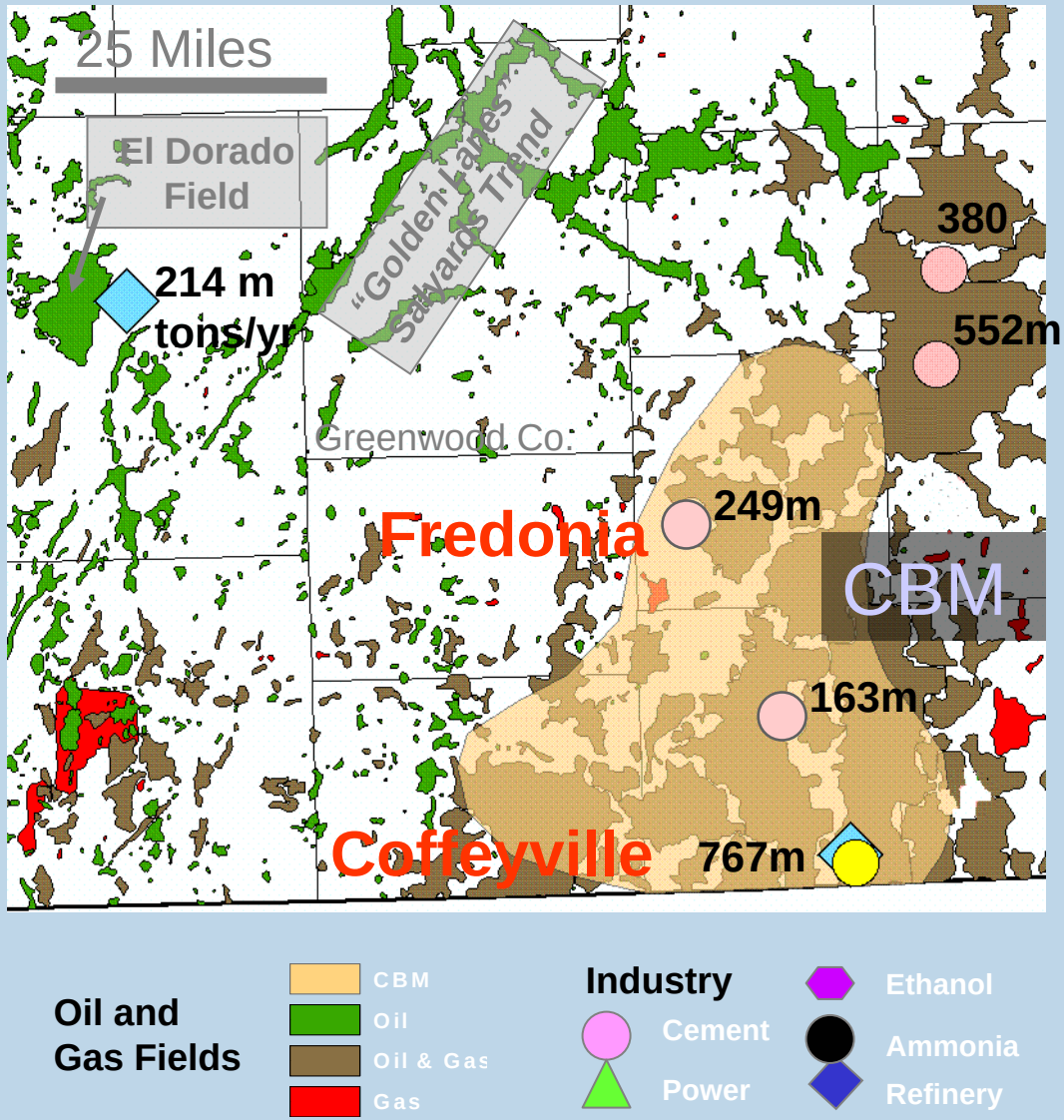
Southeast Kansas

Partially miscible and immiscible CO_2 EOR

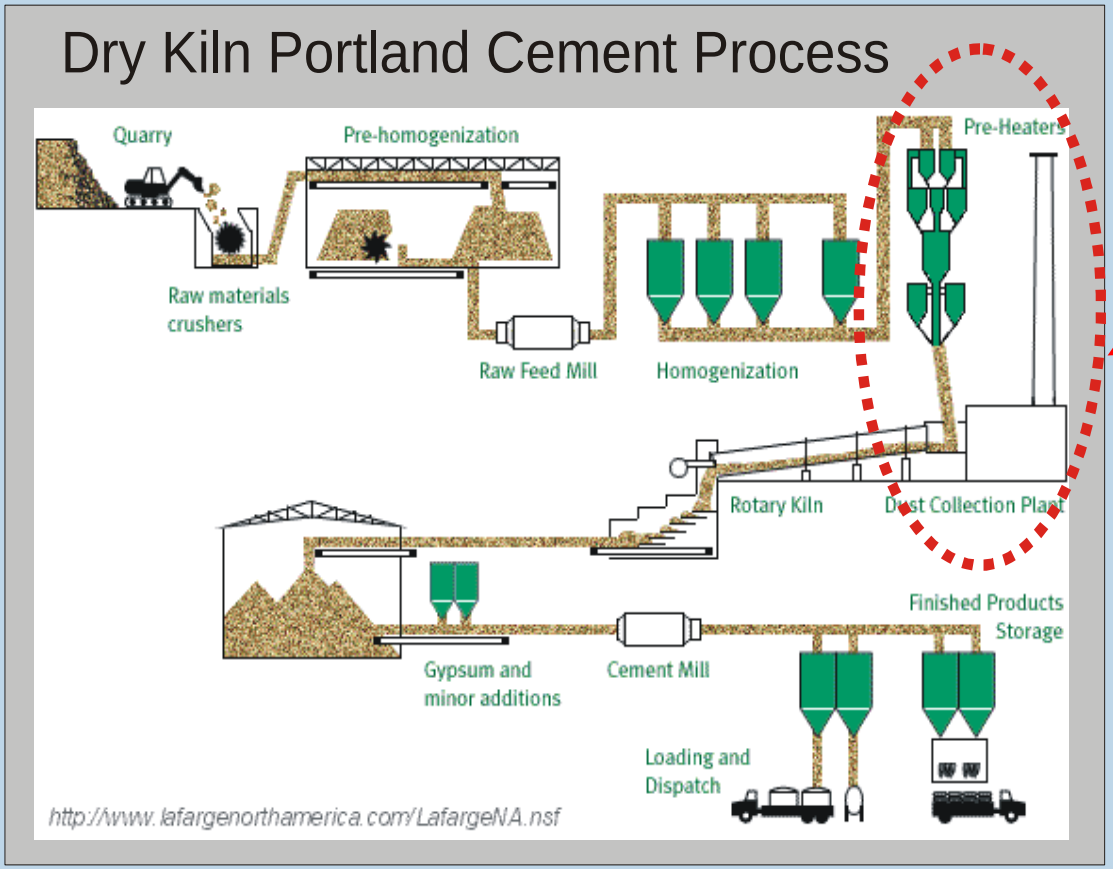
- **El Dorado**
- **Salyards Trend**,

Enhanced Coalbed Methane (N_2 and CO_2)

Cement plant gas stream may be best suited for ECBM



Cement Production



Calcination Process

$CaCO_3 > CaO + CO_2$

0.51 tonnes CO2 / tonne 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%

682 tons/day at 332° F (167° C)

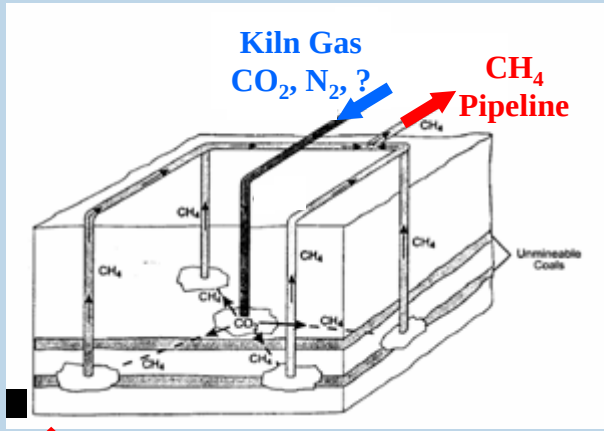
Dehydrate

	% 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)

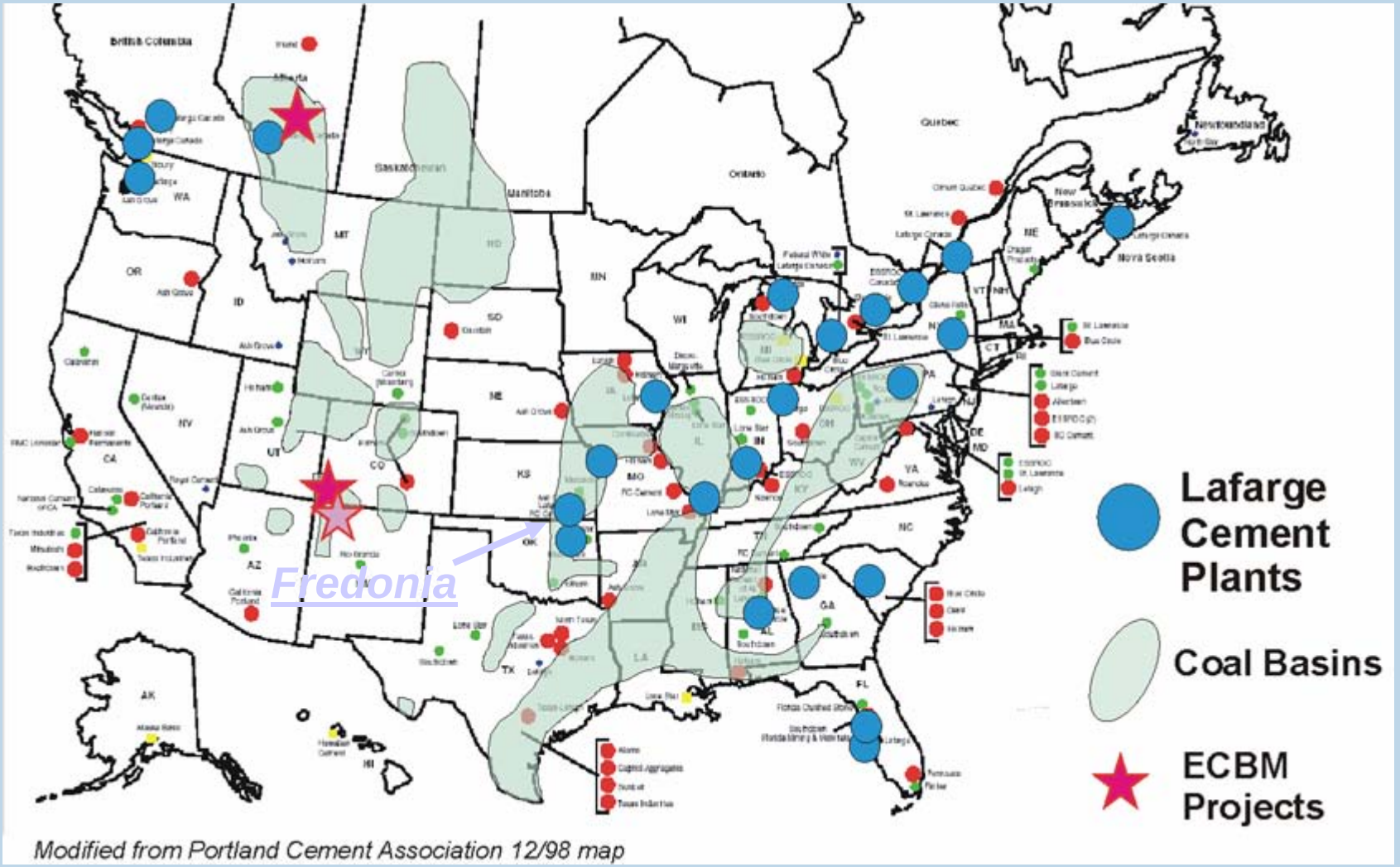


Direct or Modified

Co-generation

400°C

Cement Plants and Coal Basins

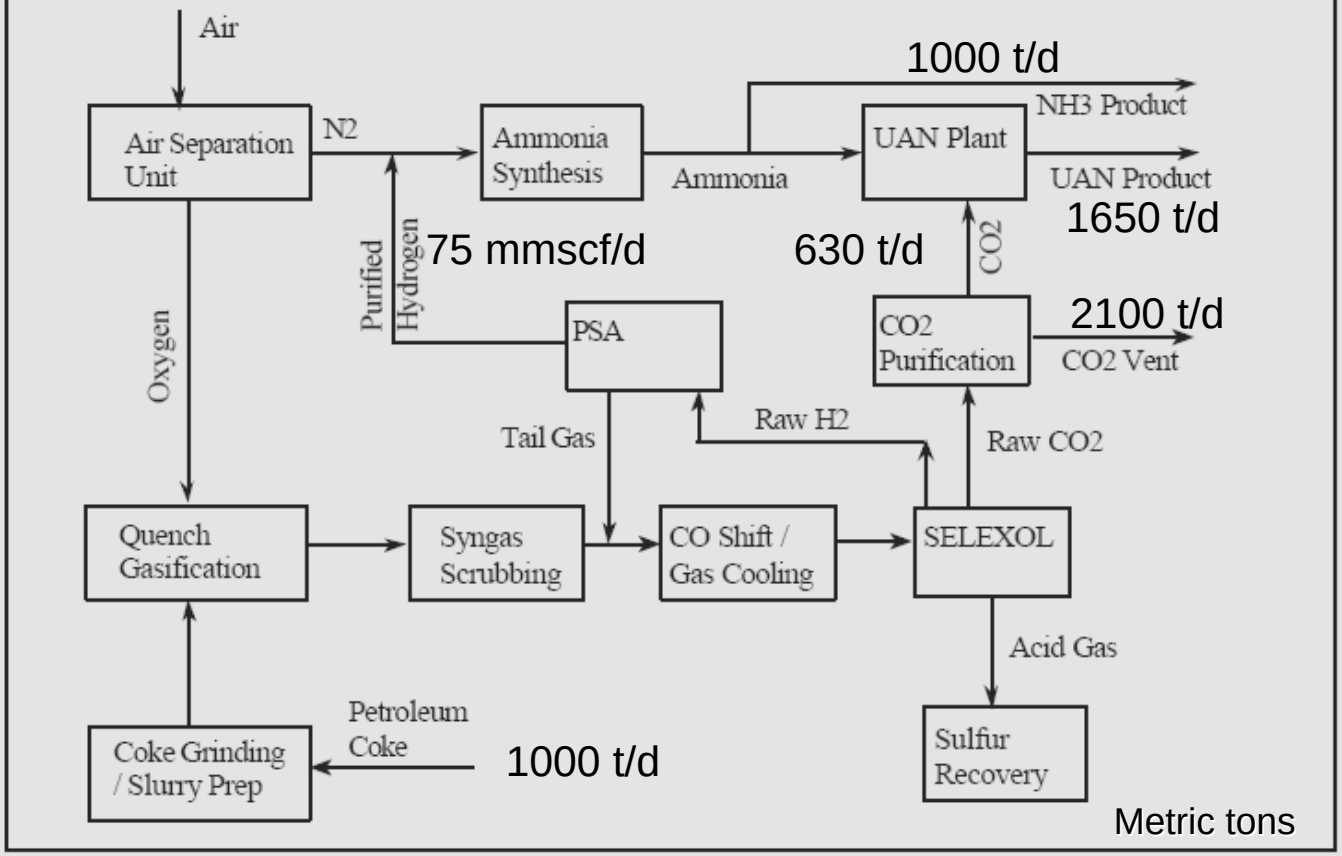


Modified from Portland Cement Association 12/98 map

Coffeyville Resources

Coke to H_2 Gasification Plant for Ammonia & CO_2

Coffeyville Coke Gasification to Ammonia Project

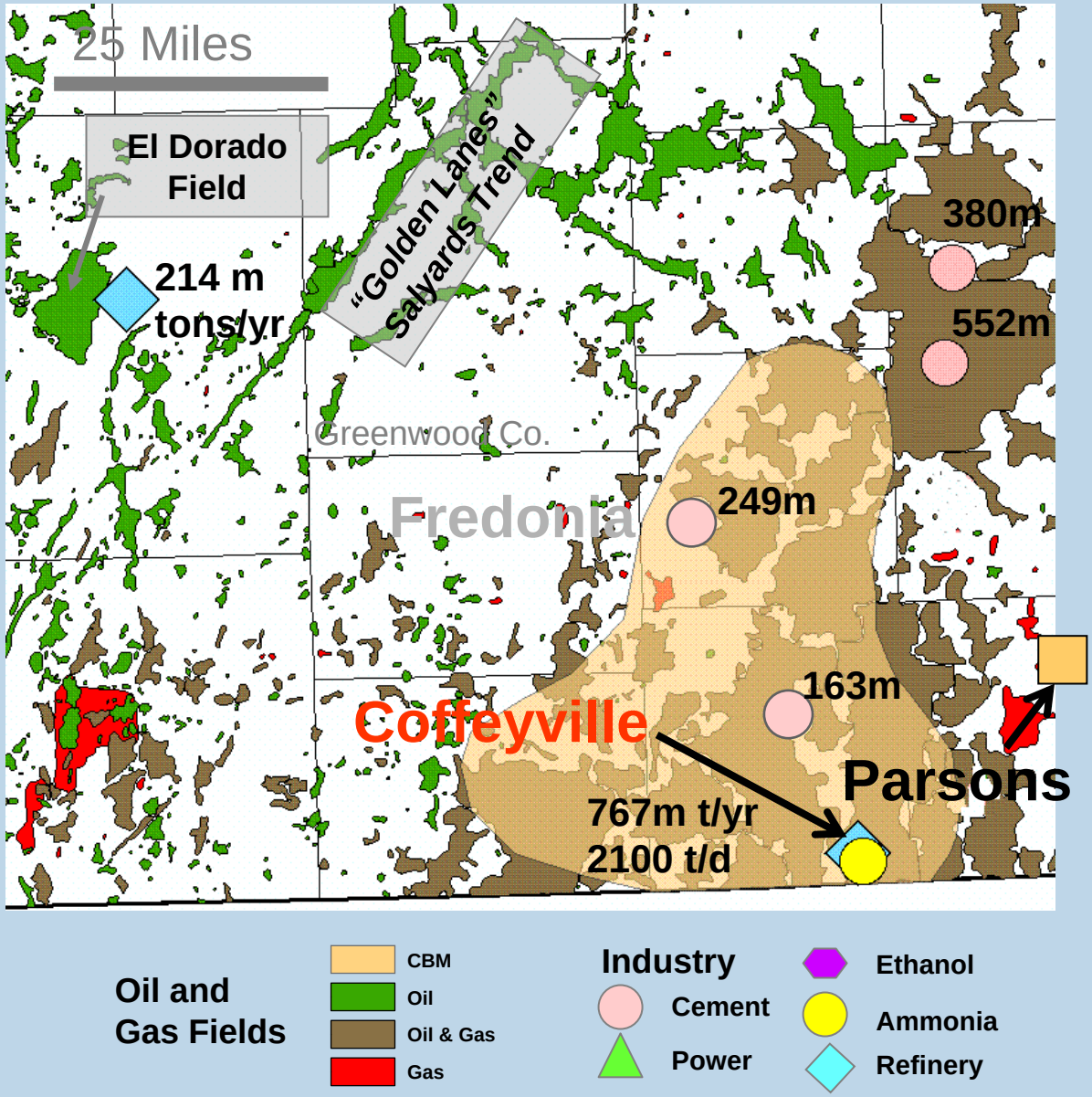


Southeast Kansas

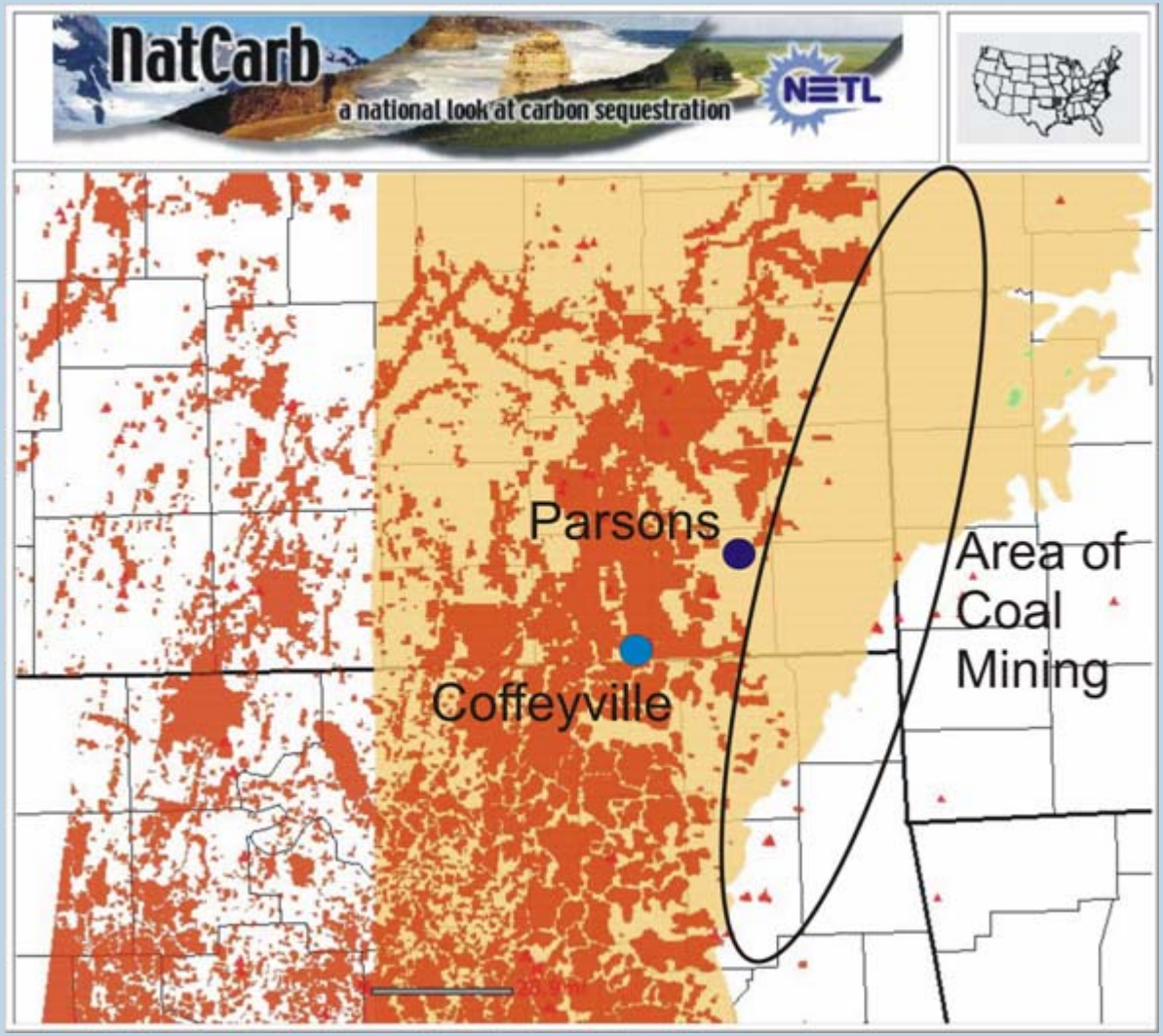
Miscible, partially miscible and immiscible CO_2 EOR

- El Dorado
- Salyards Trend
- Oklahoma

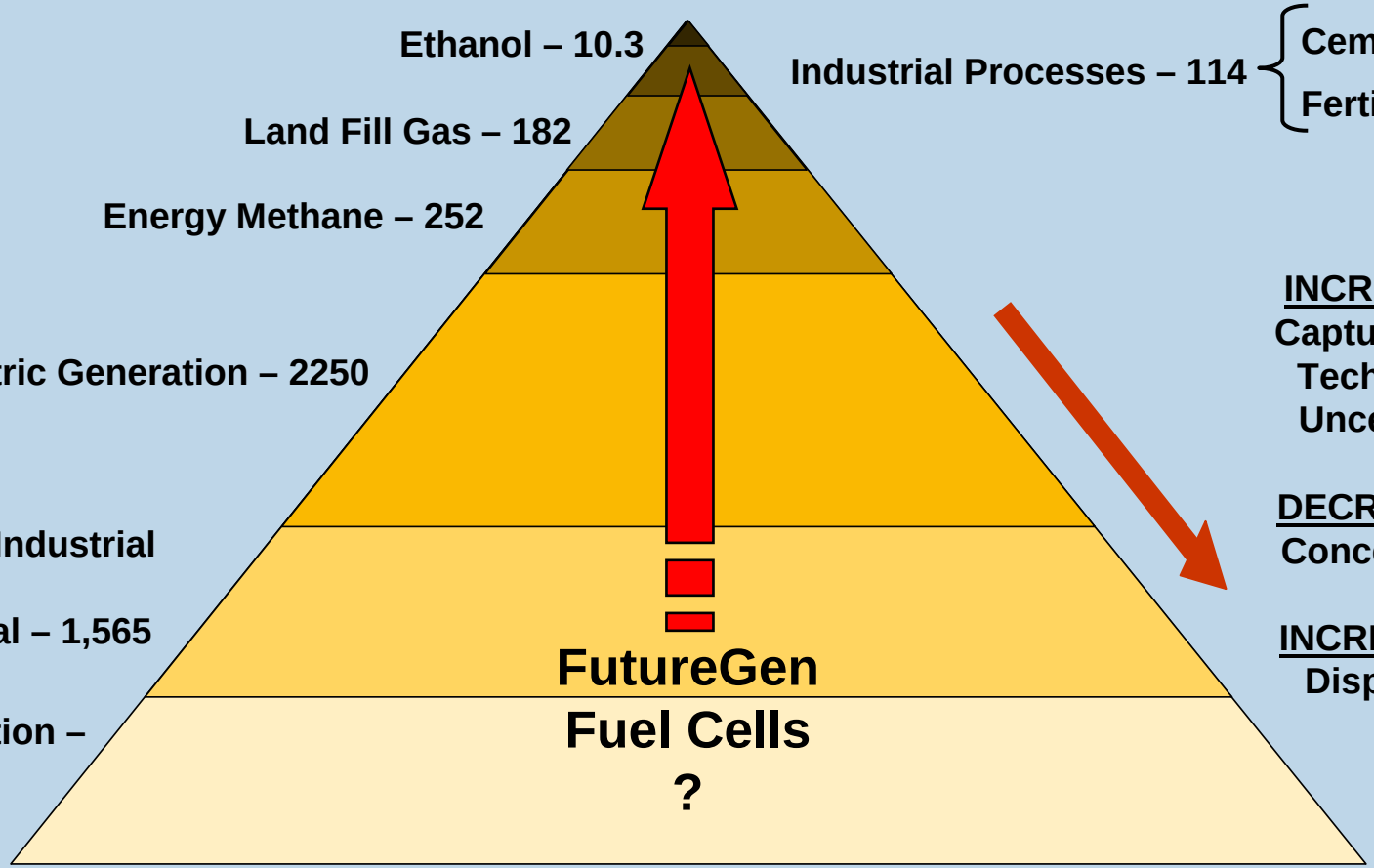
Enhanced Coalbed Methane (N_2 and CO_2)



Oil & Gas Fields Plus Coal Basins



Greenhouse Gas Resource



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

INCREASING
Capture Costs
Technology
Uncertainty

DECREASING
Concentration

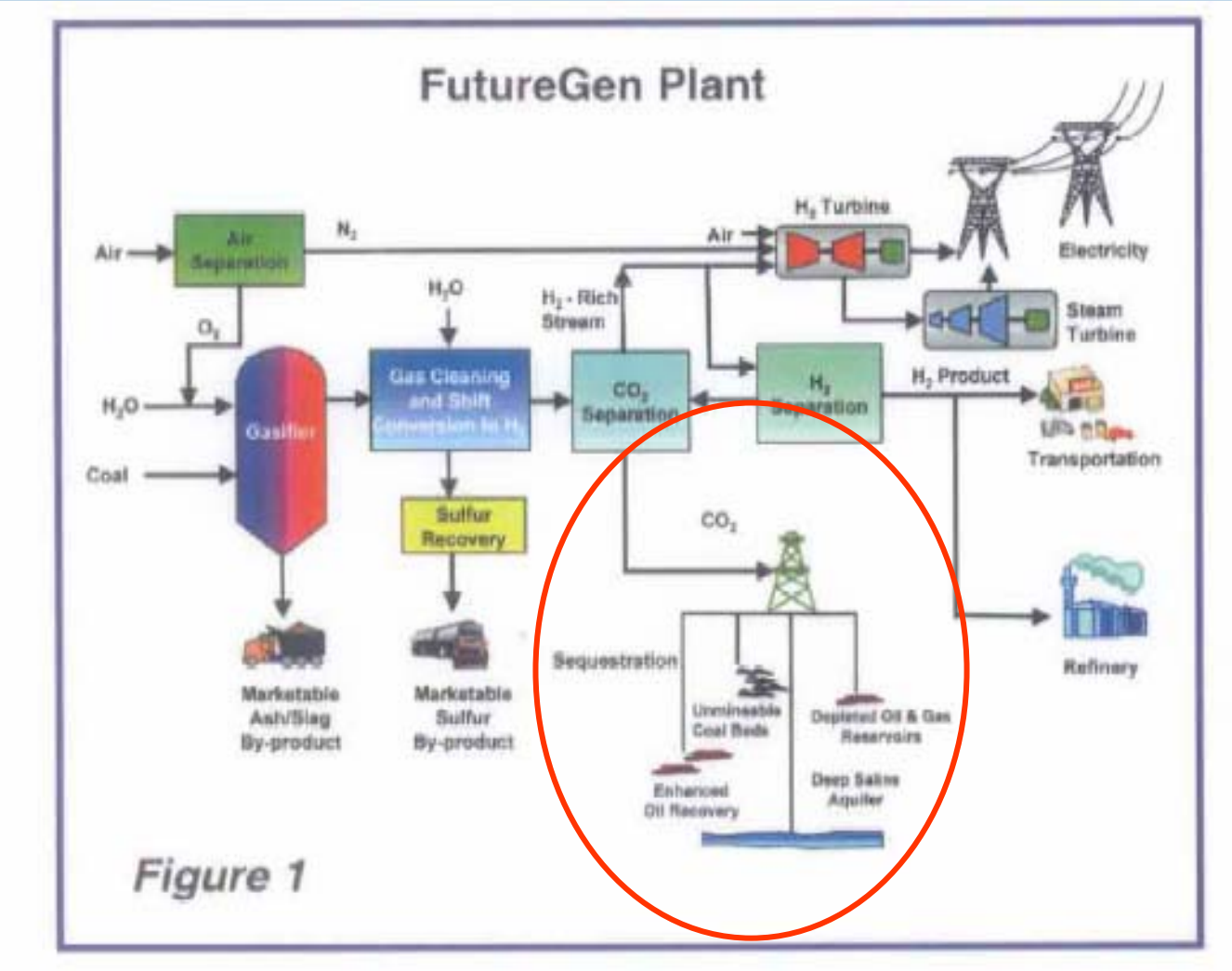
INCREASING
Dispersion

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

Total GHG Emissions 6,873 Million Metric Tons

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

FutureGen


FutureGen Plant
Air
Air Separation
N_2
Air
H_2 Turbine
Electricity
O_2
H_2O
H_2 - Rich Stream
Steam Turbine
H_2O
Gasifier
Gas Cleaning and Shift Conversion to H_2
CO_2 Separation
H_2 Separation
H_2 Product
Transportation
Coal
Sulfur Recovery
CO_2
Refinery
Marketable Ash/Slag By-product
Marketable Sulfur By-product
Sequestration
Unmineable Coal Beds
Depleted Oil & Gas Reservoirs
Enhanced Oil Recovery
Deep Saline Aquifer
Figure 1

Challenges

Size and Scope of Sequestration

1 Million Metric Tons Per Year

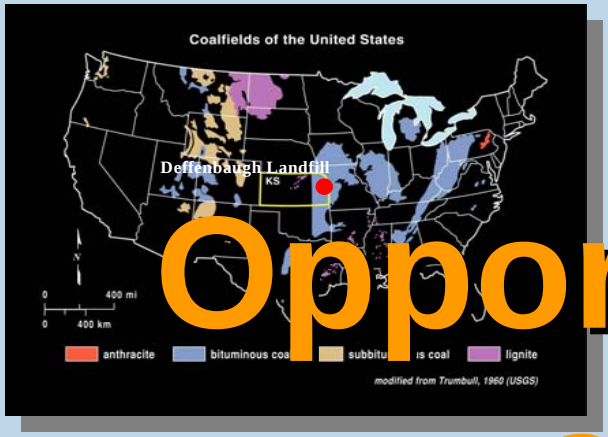
- 50 MMCF/Day (2650 tonnes/day)
- 124 kWh/tonne to compress and deliver (1,500psi or 10,000 kPa)

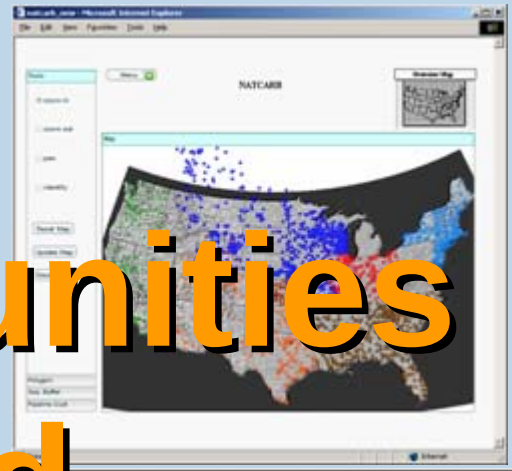
  (446,000 kJ/tonne)
- $300K per mile (1.6km) of pipeline

Approximately 200 Injectors

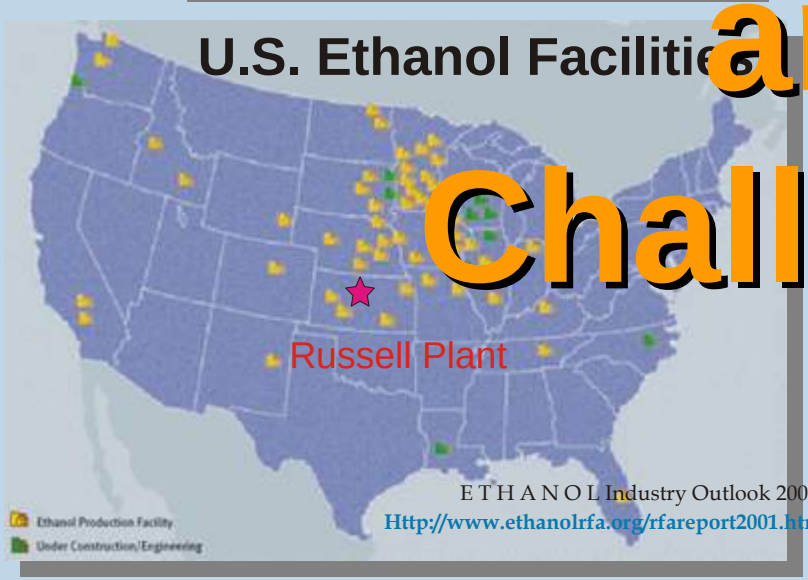
- 3.5 Producers per Injector
- Capital Costs $60 MM
- Additional 3.8 Million BO/D (520,000 tonnes/D)

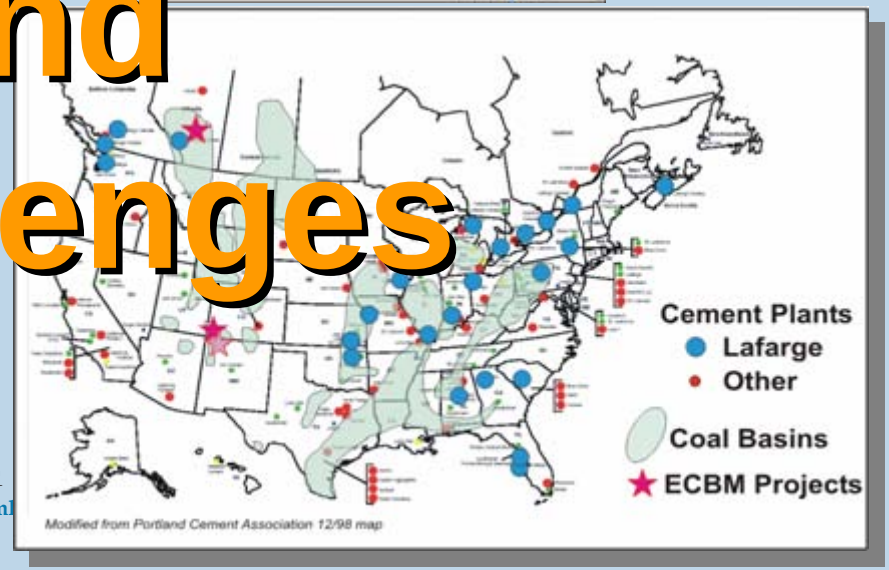
Potential Energy Systems





Opportunities and Challenges





Approach

- **Expand the number and type** of carbon sequestration opportunities in Kansas
- **Lower the cost** and optimize the value-added benefits associated with CO_2 storage
- **Develop field and carbon management practices** to minimize seepage and promote permanence
- **Develop capability to assess capacity** for carbon storage