Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Policy

Phase I and Phase II Carbon Capture and Transportation Working Group Activities of the Carbon Sequestration Regional Partnerships

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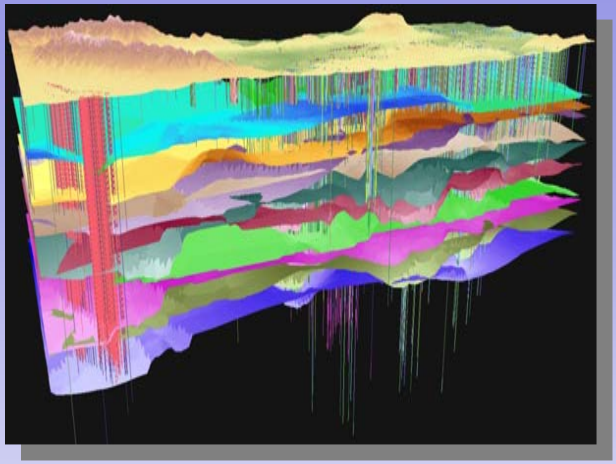
May 8-11, 2006 • Hilton Alexandria Mark Center • Alexandria, Virginia

Outline

- Overview of Regional Partnership Program Phases
- Regional Partnership CO_2 emission sources
- Regional Partnership Approaches to Identifying Regional CO_2 Capture Assessments
- RP Capture and Transportation Working Group Workshop
- Acknowledgements

RP means Regional Partnerships

Two-Phased Approach



Characterization Phase

- **7 Partnerships (40 states)**
- **24 months (2003-2005)**

Validation Phase

- **4 years (2005-2009)**
- **All 7 Partnerships Continued**
- **$100 million federal funds**
- **$45 million in cost share**

Deployment Phase

- **8 years (2009-2017)**
- **Several Large Scale Injection Tests**

Regional Partnership Capture Working Group Members

Regional Partnerships:
- Susan Capalbo* - Big Sky
- Massoud Rostam-Abadi* - Illinois Basin (MGSC)
- Bruce Sass* - MRSCP
- Melanie Jensen* - PCOR
- Richard Rhudy* - SECARB
- Frank Zhang* - Southwest
- John Ruby* - WestCarb

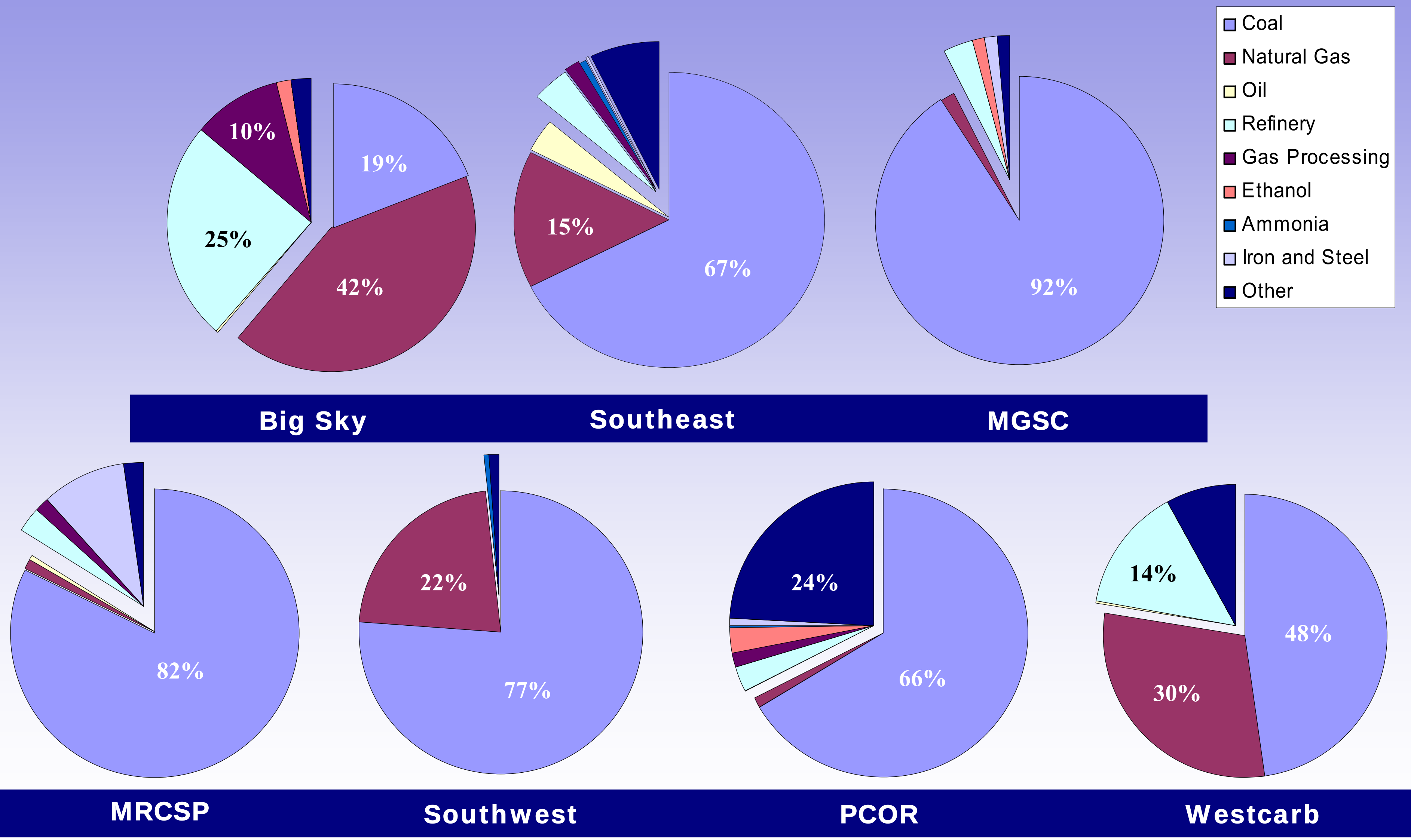
U.S. DoE FE/NETL:
- José D. Figueroa*
- Robert Wright

SAIC:
- Christopher Mahoney
- Ramesh Srivastava

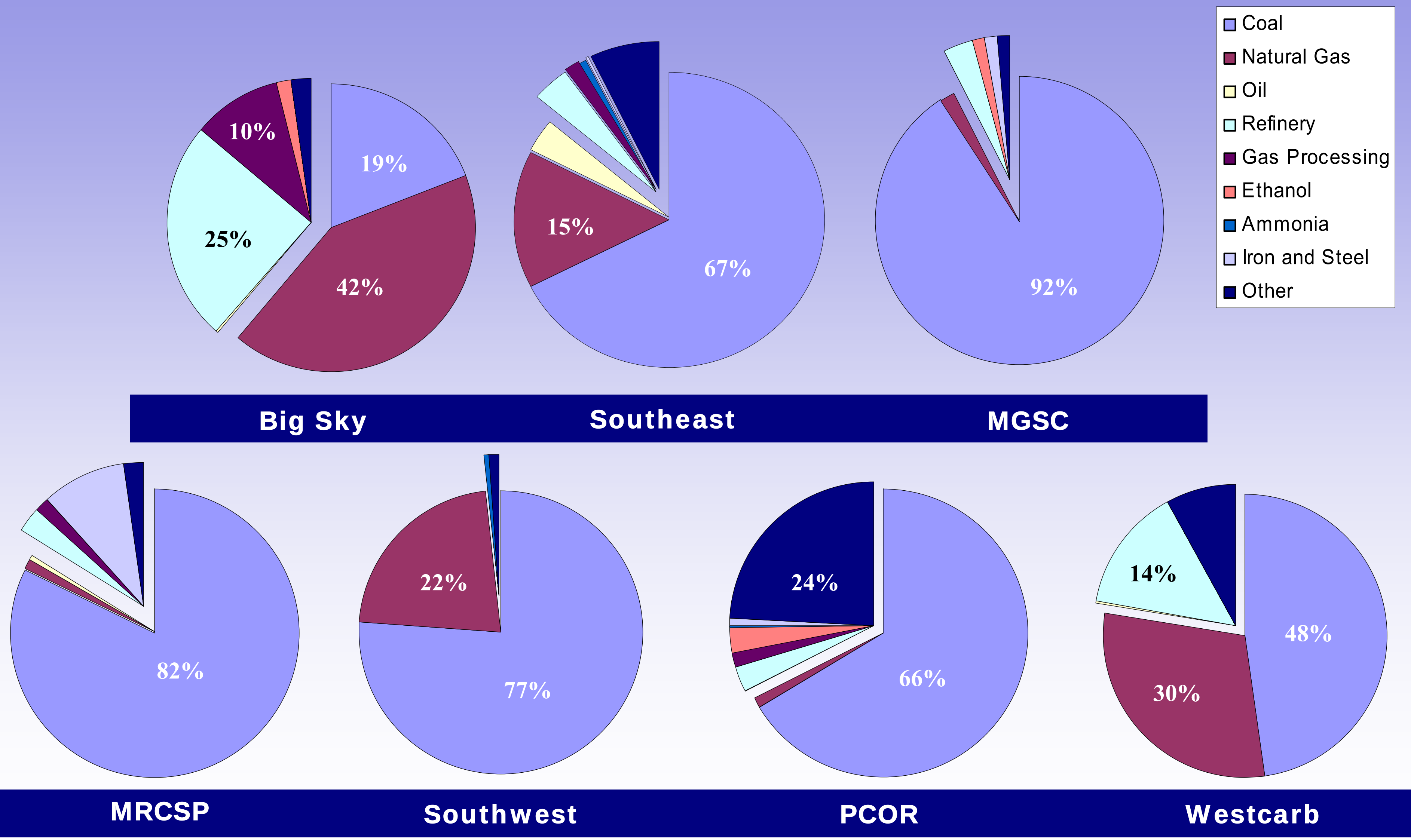
* Co-Authors

Regional CO_2 Emission Sources

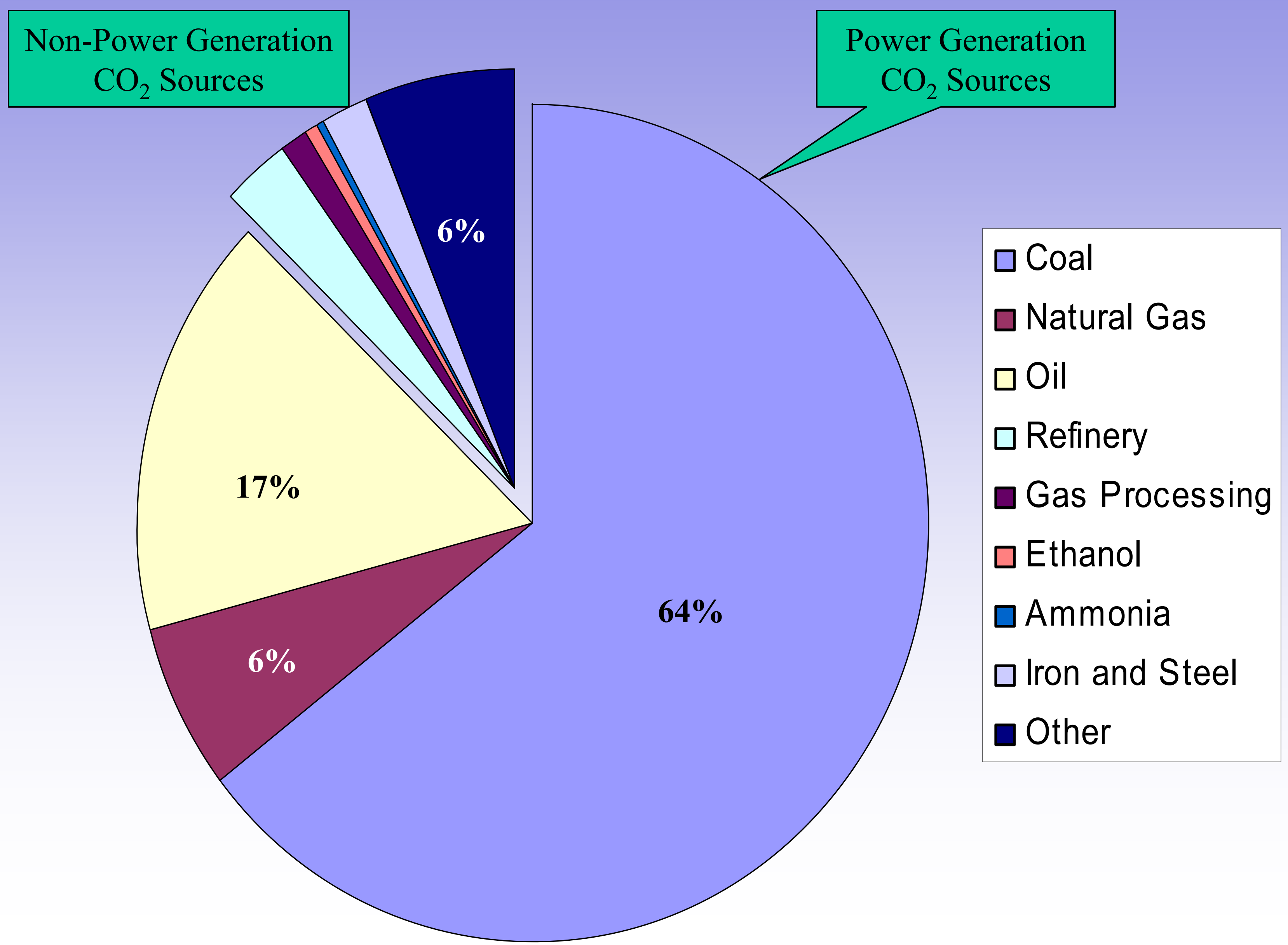
Regional Partnership Emission Profile



Regional Partnership Emission Profile



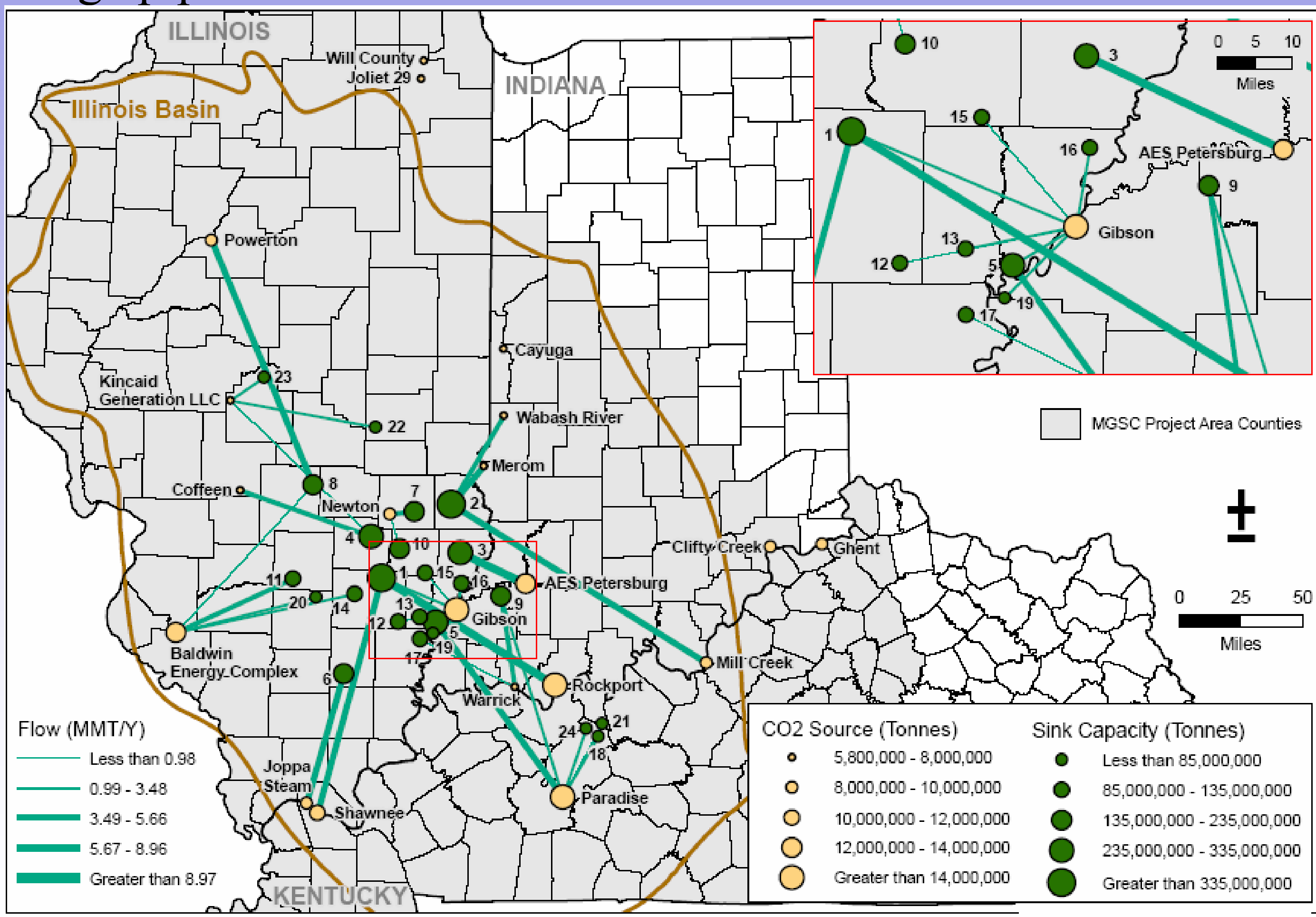
Summary
Regional Partnerships Emission Profile



Regional Partnership Approaches to Identifying Regional CO_2 Capture Assessments

MGSC: 50% Reduction with EOR and ECBM Benefits

- 15 power plants, 128 MM mt/y CO_2 reduction , ~7,746 MW electricity loss
- 82% of storage capacity including all EOR and ECBM
- Average pipeline distance 57.4 miles



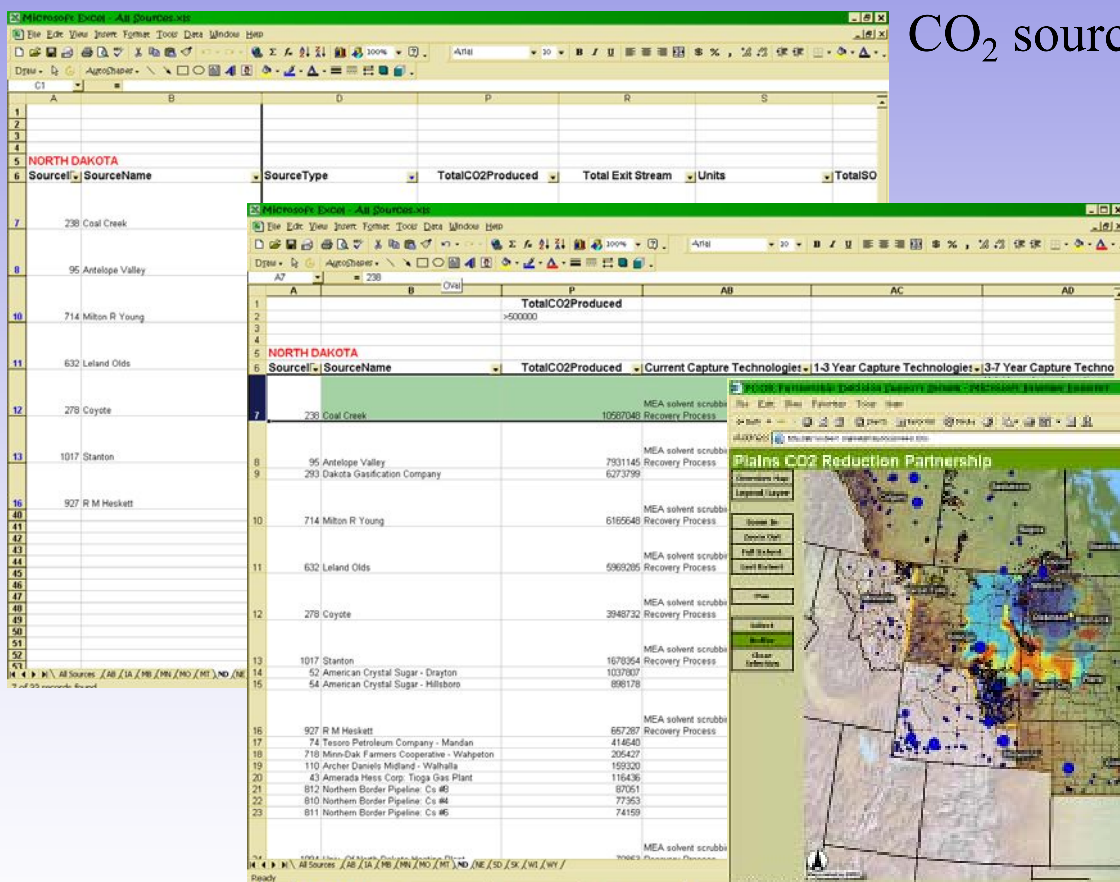
Cost effective source to sink routing developed with Lingo Optimization Model.

MGSC: CO_2 Sequestration Cost

Emission reduction level	50%	25%	10%
Emissions sequestered, MMT/Y	128.4	64.0	27.1
Averaged pipeline distance, mile	57.4	26.7	22.2
Sink capacity used, %	82%	41%	18%
Annual cost, $MM/Y			
Capture	6,867.7	3,422.6	1,445.8
Transportation	138.7	47.3	26.6
Injection	230.8	–91.4	–276.2
Subtotal cost	7,237.2	3,378.5	1,196.3
CO_2 sequestration cost, $/tonne	56.4	52.8	44.2
Electricity loss, MW	7,746	3,873	1,634
Average increase in COE, mills/kWh	22.5	10.5	3.7

Doubling Effect in the Illinois Basin Partnership when 50% CO_2 Emission Capture Considered.

PCOR: Matching Sources with Capture Technologies and Geologic Sinks



CO_2 sources most likely to come from:

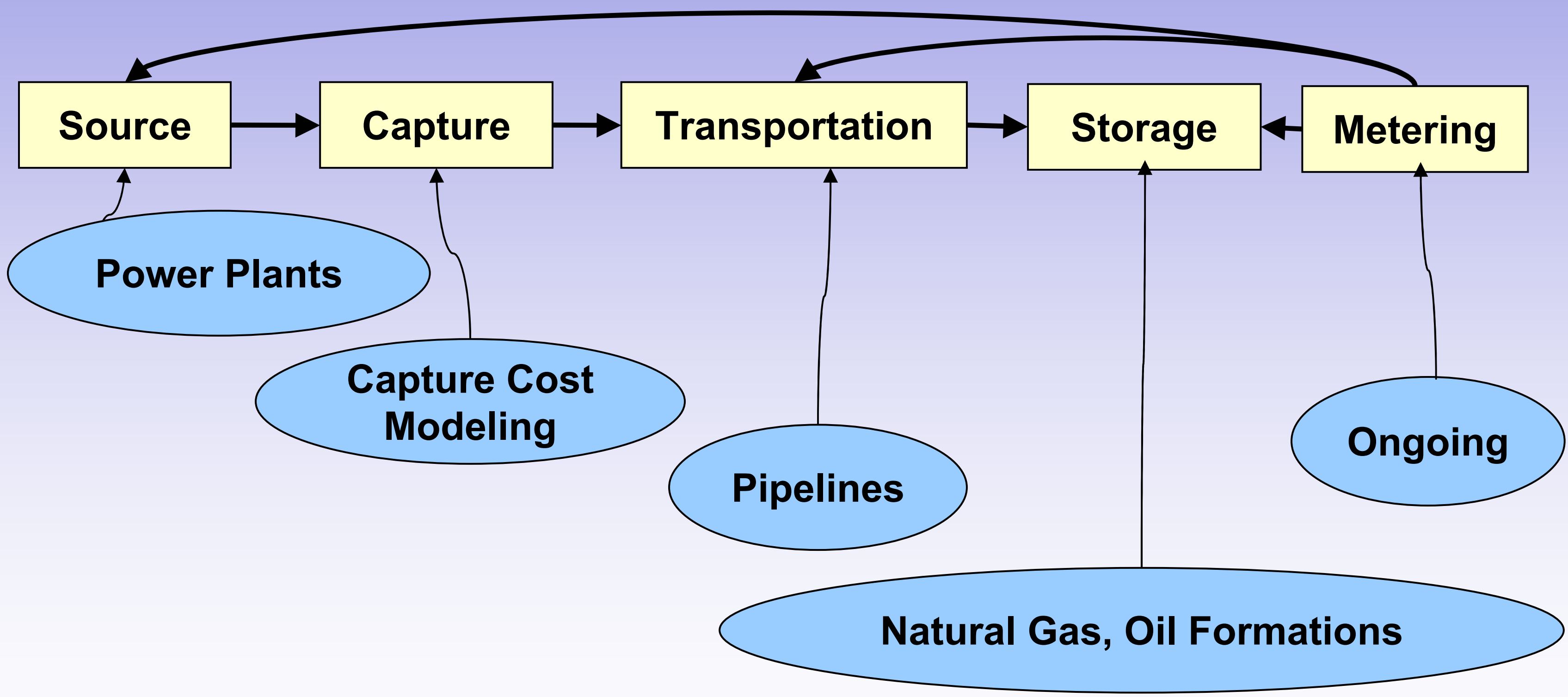
- Coal fired Power Plants
- Ethanol Production
- Oil & Gas Processing
- Cement/Clinker Production

PCOR: Preliminary Estimates of the Costs of Sequestration Strategies

Source to Sink Analysis for Power and Non-Power Generation Industries

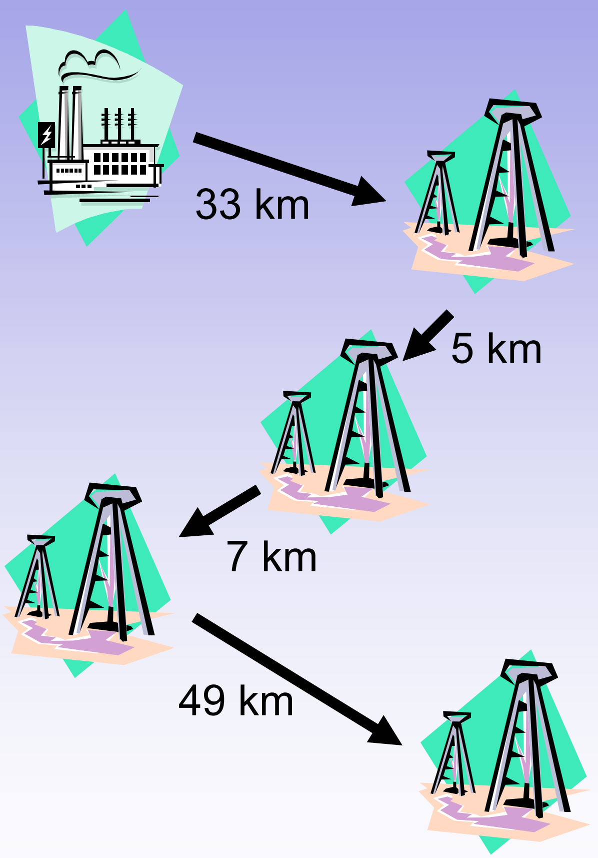
Strategy/Source Type	CO_2 Emissions, tons CO_2/yr (assuming an 80% capacity factor)	Approximate Distance from Sinks, mi	Capture or Avoided Cost (for power plant), \$/ton CO_2	Value of By-Products, \$/ton CO_2	Cost of the Strategy (not including actual injection, MMV, etc), \$/ton CO_2
power plant/EOR	8,469,638	75	26.69	114.24	-87.55
power plant/ECBM	8,469,638	100	26.69	0.10	26.59
power plant/saline aquifer	8,469,638	25	26.69	0.00	26.69
ethanol plant/EOR	53,536	150	9.00[d]	114.24	-105.24
ethanol plant/ECBM	53,536	175	9.00	0.10	13.40
ethanol plant/saline aquifer	53,536	120	9.00	0.00	13.50
cement plant/EOR	777,086	170	43.07	114.24	-71.17
cement plant/ECBM	777,086	580	43.07	0.10	42.97
cement plant/saline aquifer	777,086	550	43.07	0.00	43.07

SWRP:
Integrated Assessment Model



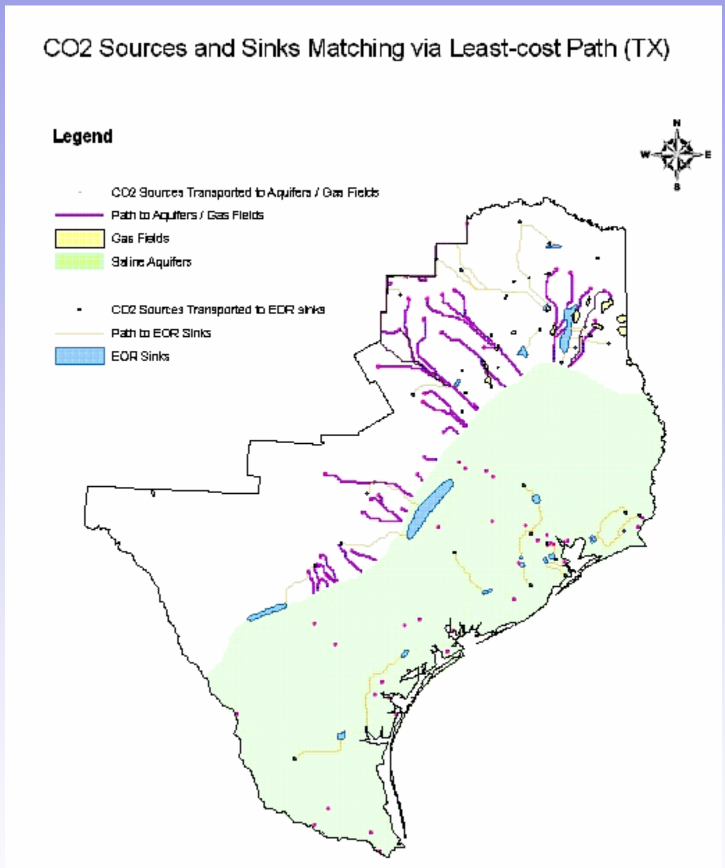
SWRP:
The 'String of Pearls' Model Framework

- Model addresses global system perspective.
  - e.g. largest sink volume, lowest overall cost, etc.
- Model calculates the distance to transport CO_2 from the source to the closest sink.
- Then calculates the distance from the first sink to the next closest sink, and so on until a network of sinks are used.



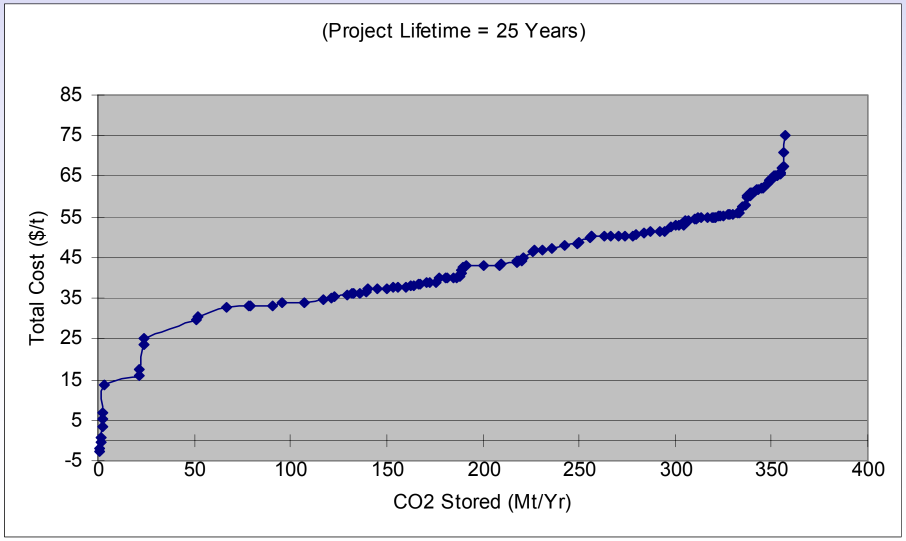
(illustrative km, picture and orientation not to scale)

SECARB: Characterization Phase
Sources and Sinks Matching

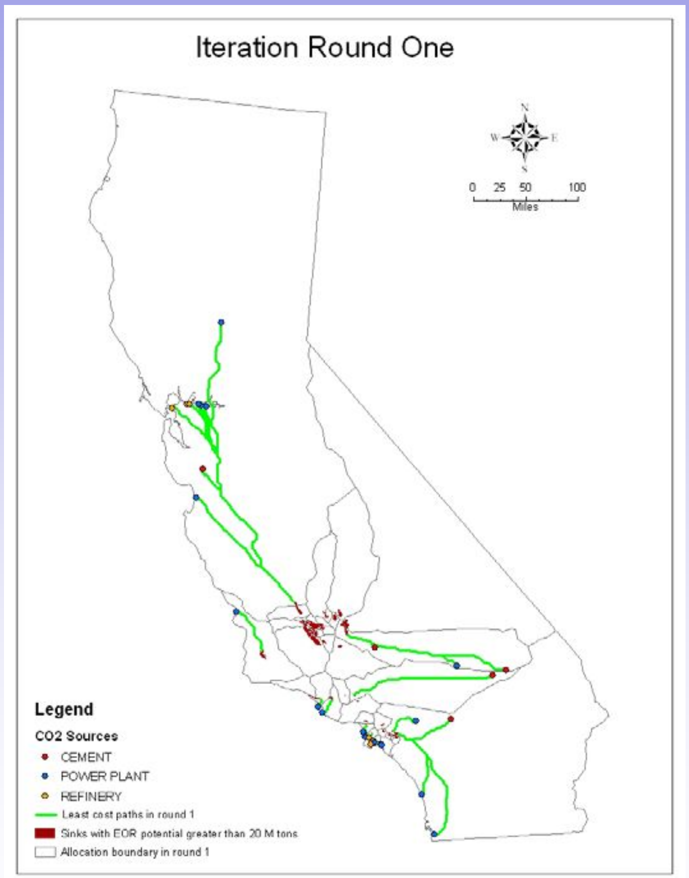


- **For sinks and sources in Texas only**
- **Least-cost path matching**
- **Sink capacity constraint is considered**
- **Transportation obstacle layers are applied**
- **A cost allocation iteration is used for source-sink matching**

Texas Marginal Cost by CO_2 Storage Rate

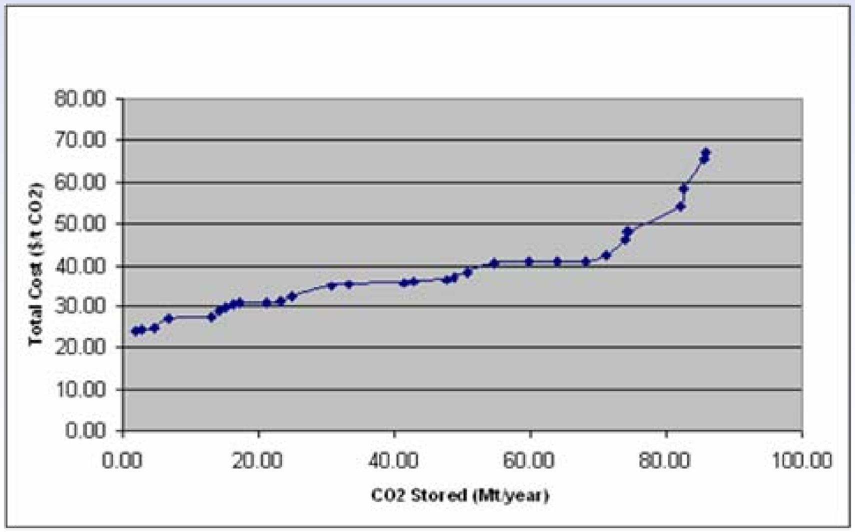


WESTCARB: Characterization Phase Sources and Sinks Matching



- For sinks and sources in California only
- Least-cost path matching
- Sink capacity constraint is considered
- Transportation obstacle layers are applied
- A cost allocation iteration is used for source-sink matching

California Marginal Cost by CO_2 Storage Rate

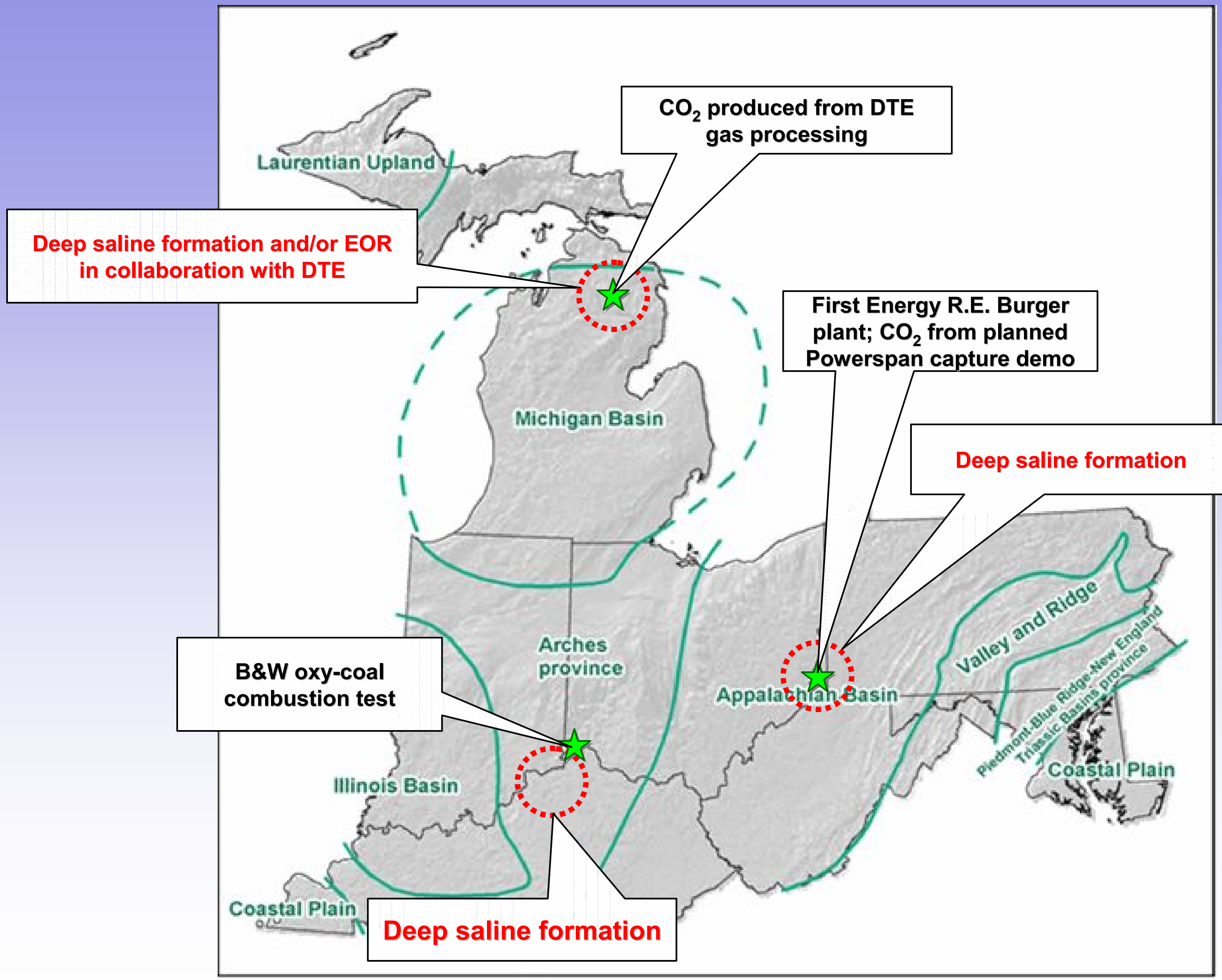


MRCSP:
Source to Sink Potential Demonstration Sites

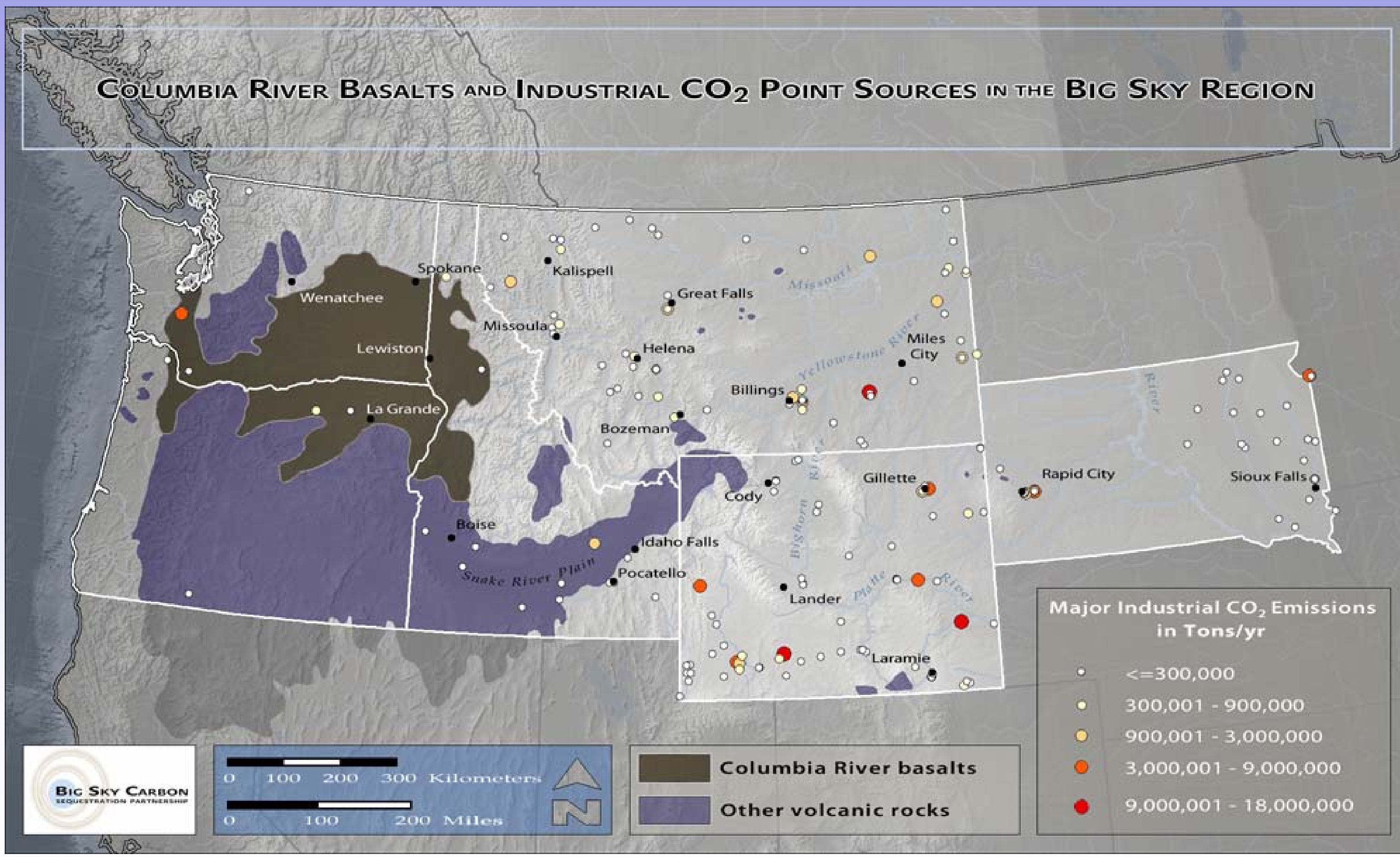
The MRCSP is evaluating CO_2 injection in deep saline formations at three locations in the region with various CO_2 sources.

- First Energy's R.E. Burger Power Plant representative of Appalachian Basin geology (Eastern Ohio) with CO_2 source from a planned Powerspan™ aqueous ammonia demonstration
- Injection of CO_2 from natural gas processing plants operated by DTE in the Northern Michigan
- Injection test in Cincinnati area with CO_2 supplied by a municipal coal-fired power plant demonstrating a Babcock and Wilcox Company oxy-combustion cycle.

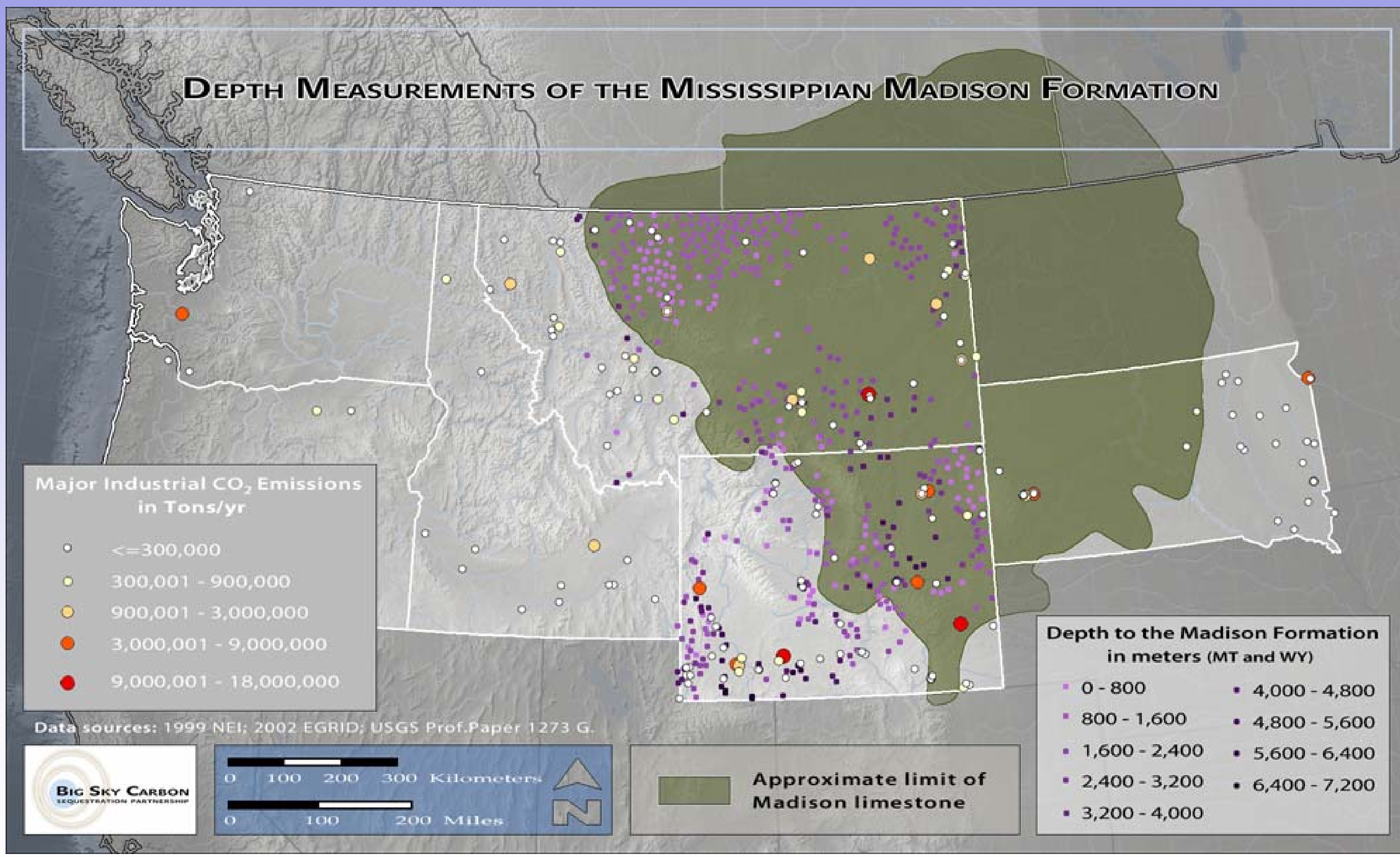
Locations of Phase II CO_2 Sites and Geologic Field Validation Tests



BIG SKY PARTNERSHIP:
Matching Sources and Basalt Sinks
Capacity of Columbia River Basalts – 100Gt CO2



BIG SKY PARTNERSHIP
Matching Sources and Carbonate Petroleum Reservoirs: Madison Formation



2^{nd} Annual Carbon Capture and Transportation Working Group Workshop

- Held on March 22-23, 2006
  - Hosted by WESTCARB
- CO_2 capture and transportation presentations from 7 Regional Partnerships.
- 30 Attendees from Government, Industry, and Academia
- Consensus building among partnerships on capture and transportation issues.

Country Perspective	Industry Perspective	Technology Developers
• USA • UK • Canada	•El Paso Western Pipeline •Praxair •EPRI	•Research Triangle Institute •Carbozyme •Cansolv • Nexant •Babcock and Wilcox •BOC Group

Highlights from Industry Presentations

- El Paso Western Pipeline Corporation:
  - Increasing competition and new pipeline construction creates conversion opportunities for smaller pipelines.
  - Obtaining R.O.W. is increasingly difficult.
  - Typically gas fired engine driven compression used – now electric motors will be used.
    - Booster compressor driven by an electric motor
      - Approximately two years to permit and construct for $12M

Highlights from Industry Presentations

- Praxair:
  - Air leakage in Oxy-fuel combustion is a significant factor associated with compression and oxygen purity.
  - Power savings in 95% [O_2] vs. 99.5% [O_2] more than offsets extra power requirements in CO_2 purification.
  - CO_2 capture is a significant issue for industrial gas companies due to:
    - Environmental concerns
    - Increasing power costs

Regional Partnership
Validation Phase Efforts

- Planned efforts by the Regional Partnerships but not necessarily by all of them.
  - Characterization of regional power and non-power CO_2 sources
  - Addressing CO_2 quality concerns (purity and pressure).
  - Monitoring existing and emerging capture technologies.
  - CO_2 transportation analysis.
  - Match CO_2 "source–technology–sink" scenarios.
  - Examine siting procedure of new coal and natural gas plants in a CO_2 sequestration market.
  - Evaluate replacement generation options due to CO_2 capture parasitic energy load.

Closing Thoughts

- Characterization Phase work developed many approaches to analyzing the implications of CO_2 capture and transportation on each region.
- Validation Phase will continue to:
  - Characterization of sources,
  - Analysis of commercial and emerging CO_2 capture technologies,
  - Consensus building among partnerships on capture and transportation issues.
  - Utilization of common baselines and approaches.
- The need for further collaborated analysis of CO_2 capture and transportation issues is essential to reducing the regional and national cost for CO_2 management in the United States.

Acknowledgements

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- **PCOR**
  - Mark Musich, Melanie Jensen, John Ruby, Jim Evans
- **SECARB**
  - Richard Rhudy, Howard Herzog, Jerry Hill
- **SWRP**
  - Brian McPherson, Howard Meyer, Mike Hirl, Barry Biediger , Peter Kobos
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