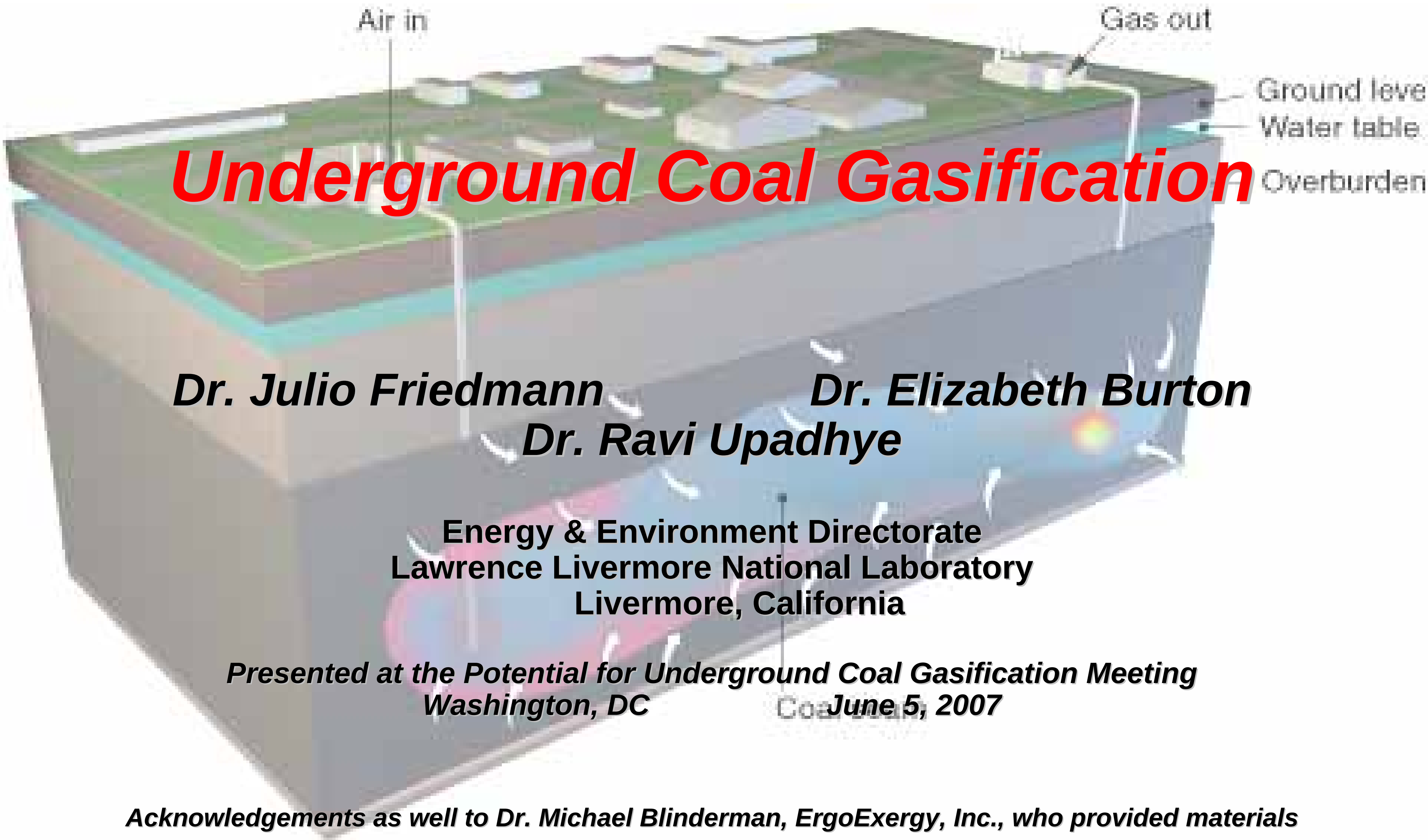

Underground Coal Gasification

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Presented at the Potential for Underground Coal Gasification Meeting
Washington, DC ***June 5, 2007***

Acknowledgements as well to Dr. Michael Blinderman, ErgoExergy, Inc., who provided materials

Conclusions regarding UCG

Advanced technology to produce syngas

Distinct cost and environmental advantages

Environmental hazards readily managed

Commercial-scale demos possible

Best Practices in Underground Coal Gasification: Pending DOE-FE Report

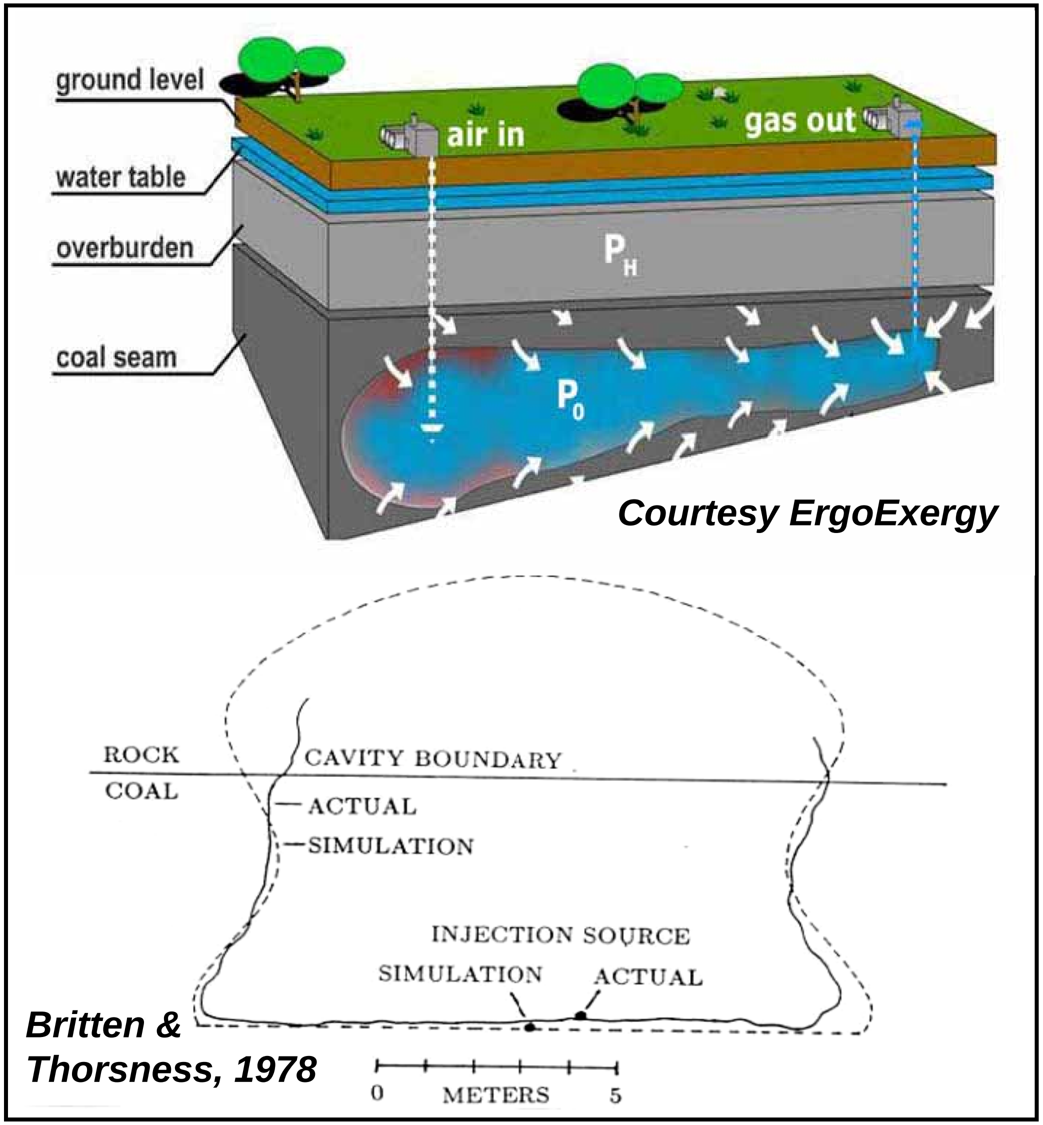
Underground coal gasification produces syngas with low capital and low operating cost

Gasification occurs in situ. The technology is well tested >40 years

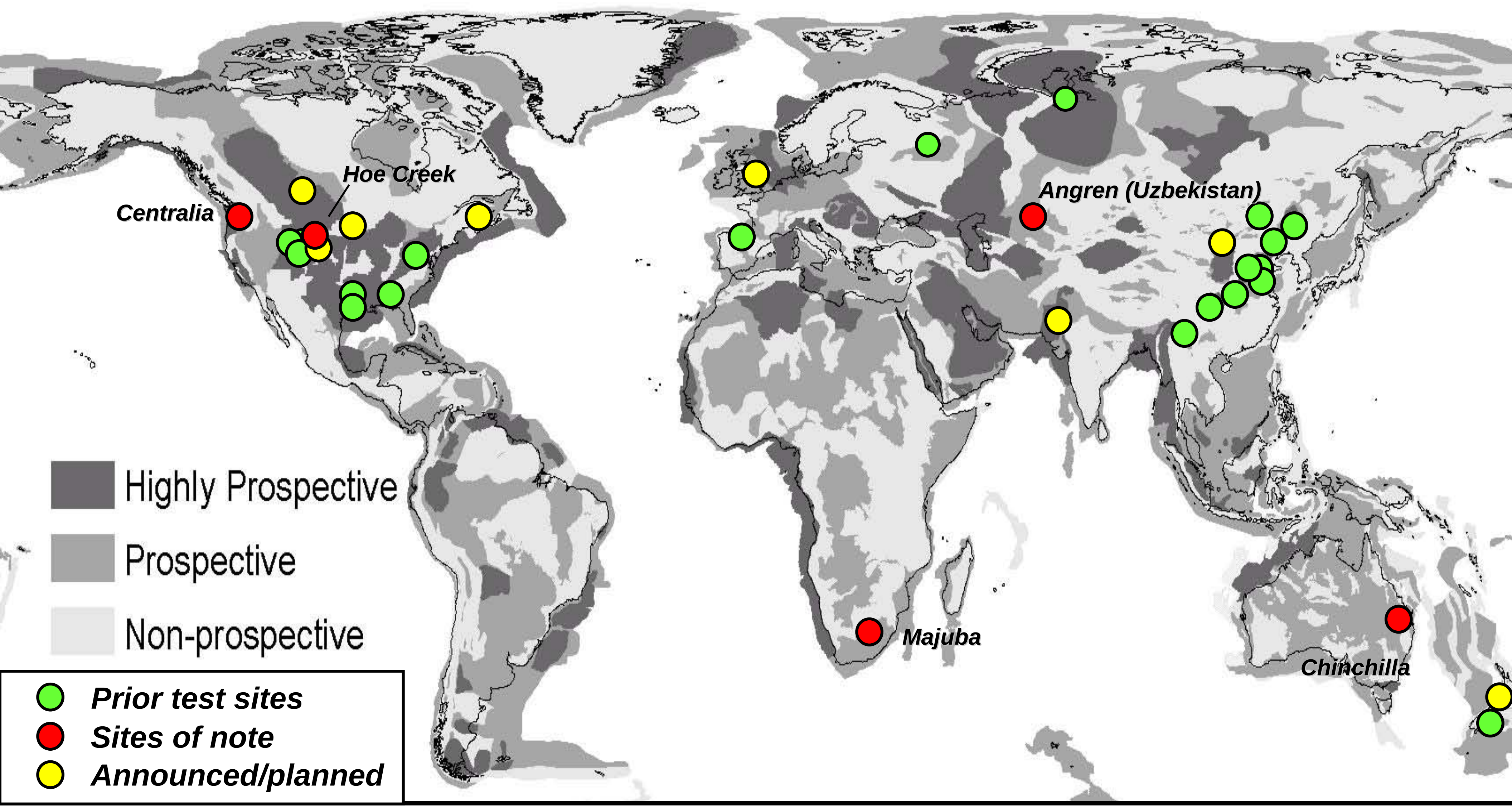
Environmental benefits
- No mining
- Much less pollution (no SO_x, NO_x; less mercury, particulates)
- Low-cost H_2 production

Economic benefits
- No gasifier purchase, operation
- No coal purchase or transport
- Low-cost power generation

Carbon Management
- Lower cost CO_2 separation
- Good coincidence between UCG and sequestration sites



There has been a dramatic increase in commercial UCG interest world-wide



Over 33 US, 66 FSU projects, and 20 other international pilots

New projects proceeding rapidly with aims for a variety of different products

Linc Energy, Australia (Chinchilla)

- First gas, 1999; continuous for 2.5 years
- 35,000 tons brown coal evacuated
- Current plans for CTL plant

Eskom, S. Africa (Majuba)

- Ignition Jan. 2007; electric power
- Bituminous coal
- Planning 1000 MW IGCC step out this year

GAIL, India

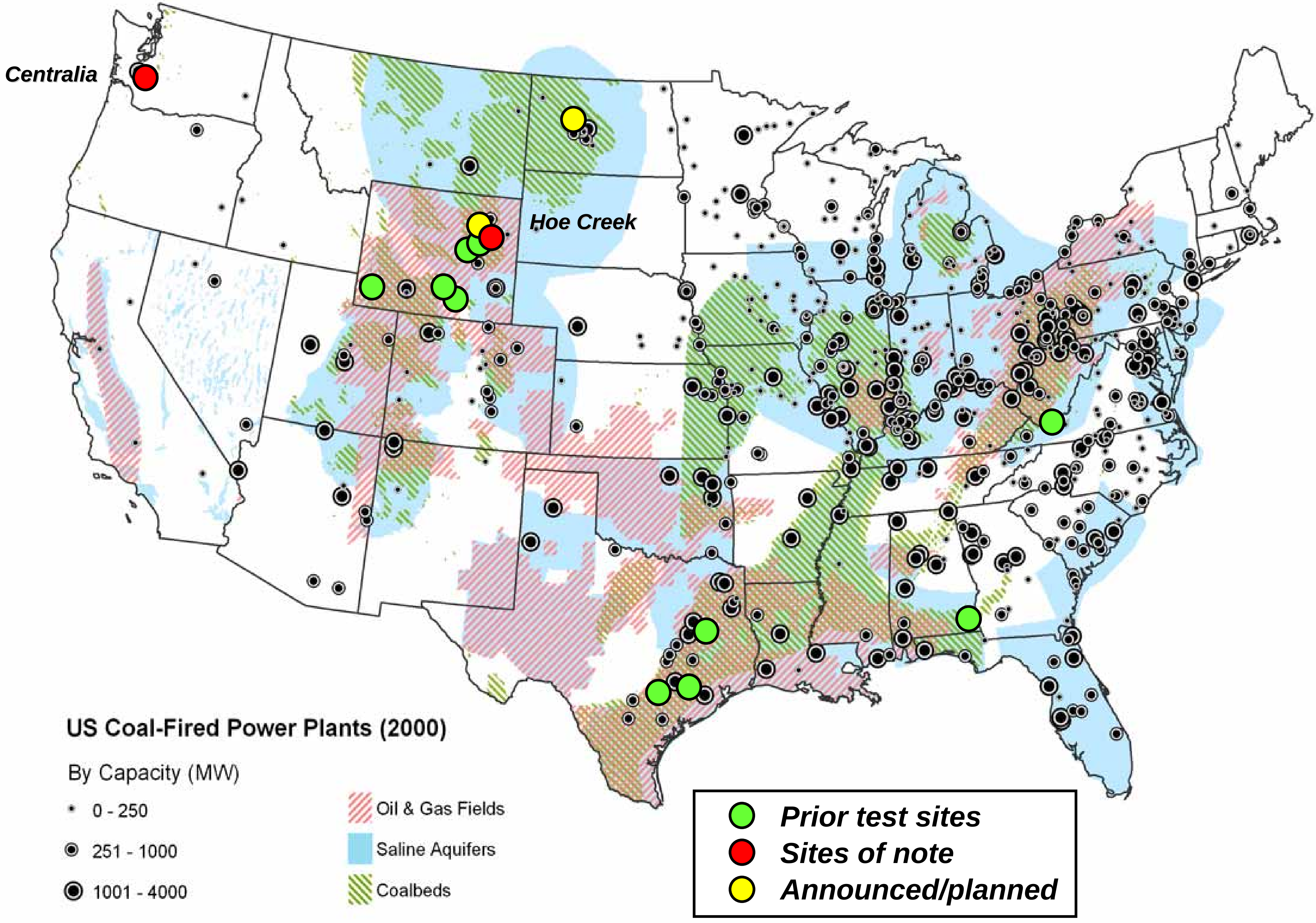
- Scheduled production, 2009
- Lignite coal, planned electric power

XinAo, China

- Pilot ignition, Aug. 2007
- Sub-bituminous; planned methanol plant

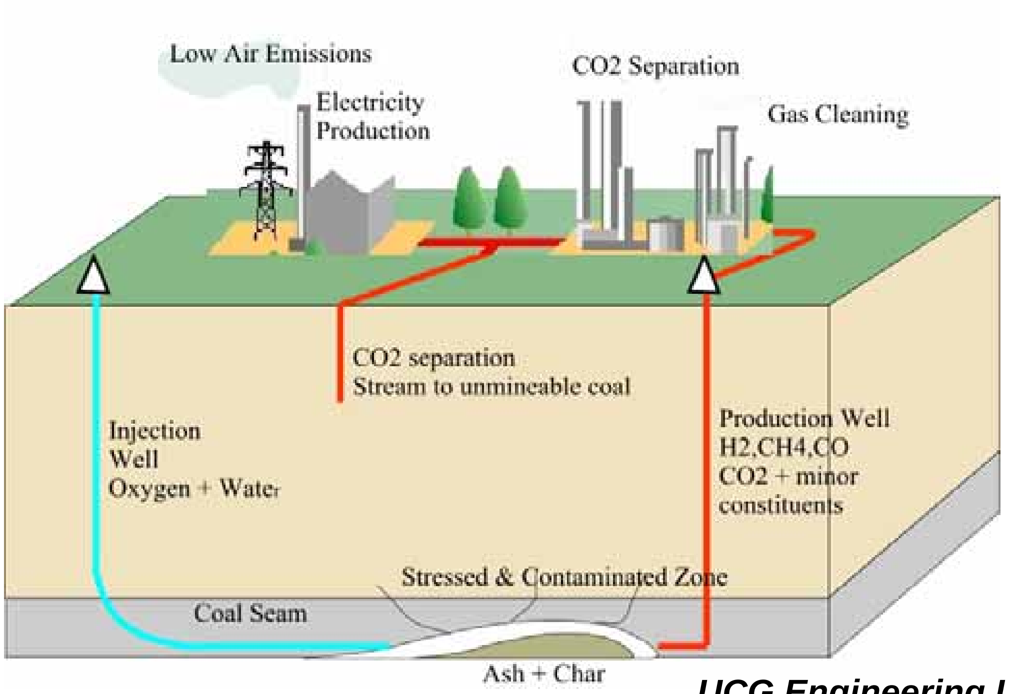
Other companies planning or operating hydrogen, synthetic natural gas, F-T, and power with CCS

US UCG projects

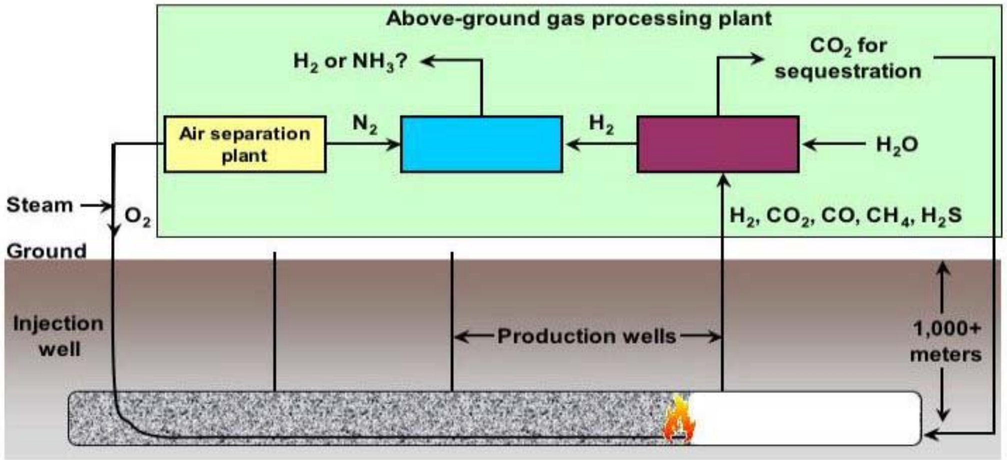


UCG has substantial economic benefits

- No coal mining; no coal purchase or transport; no ash management
- No gasifier or boiler purchase
- UCG syngas tested with off-the-shelf turbines
- Great flexibility in products (power; synthetic NG, liquids),
- Very low cost H_2 production ($0.60/mcf; $2-3/MBTU)



UCG Engineering Ltd.

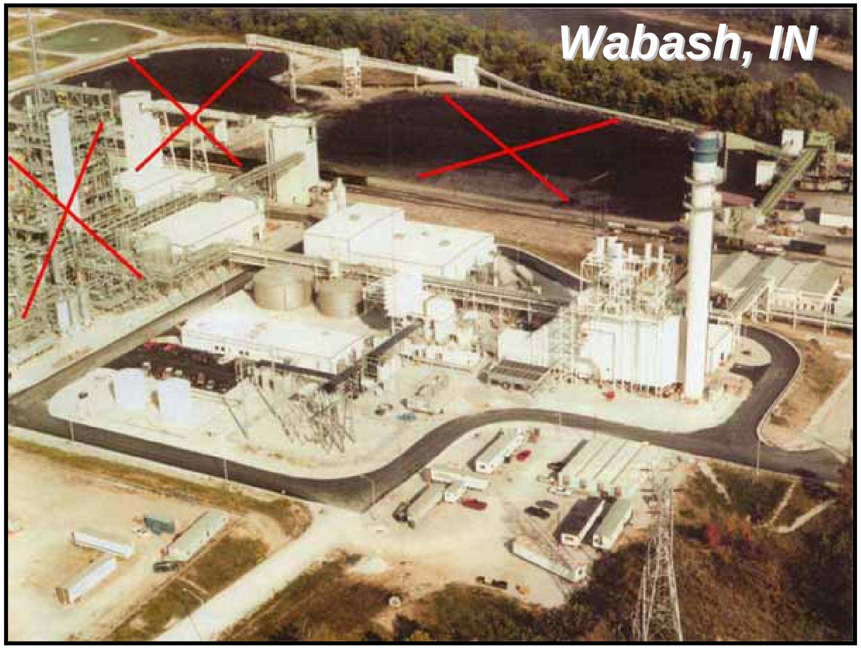


These aspects have increased interest in developing countries (India, China) with high sulfur & high ash coals.

UCG has substantial environmental benefits

- No coal mining; no coal purchase or transport; no ash management
- Smaller surface footprint
- No NO_x
- 50% volume of particulates. mercury, arsenic, sulfur, tar
- No SO_x; sulfur management straightforward
- Synergies with carbon management

These aspects have increased interest in developing countries (India, China) with high sulfur & high ash coals.



Courtesy ErgoExergy

UCG has real engineering and environmental issues

Engineering issues

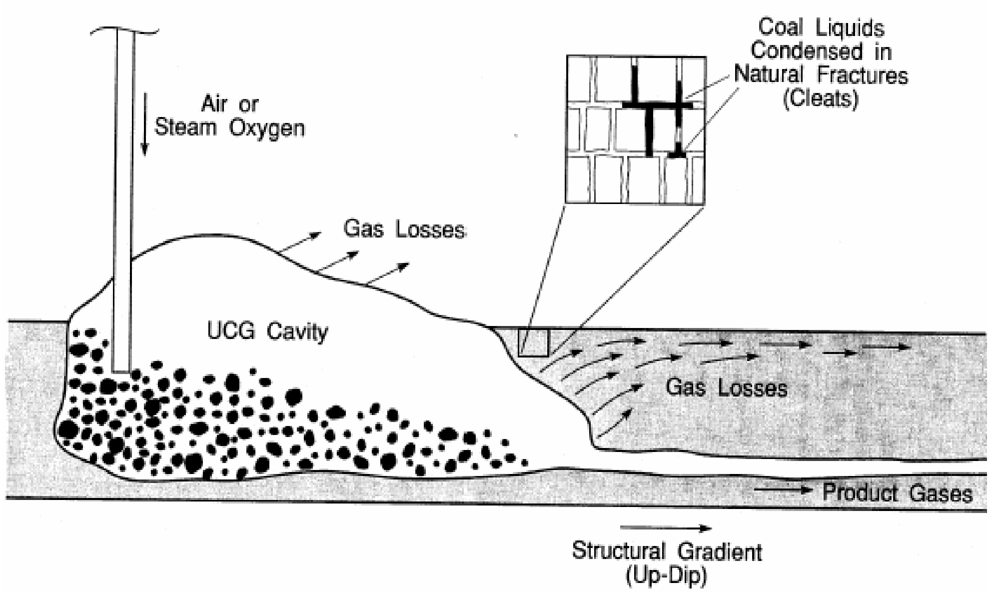
- Cannot control all aspects of gasification
- Volume and composition of syngas fluctuate; still difficult to predict
- Must design surface facilities to handle tar, H_2S

Environmental issues

- Like long-wall mining, must manage subsidence
- Concerns over groundwater contamination hazard and risks

These issues can be managed readily by careful site selection and operation

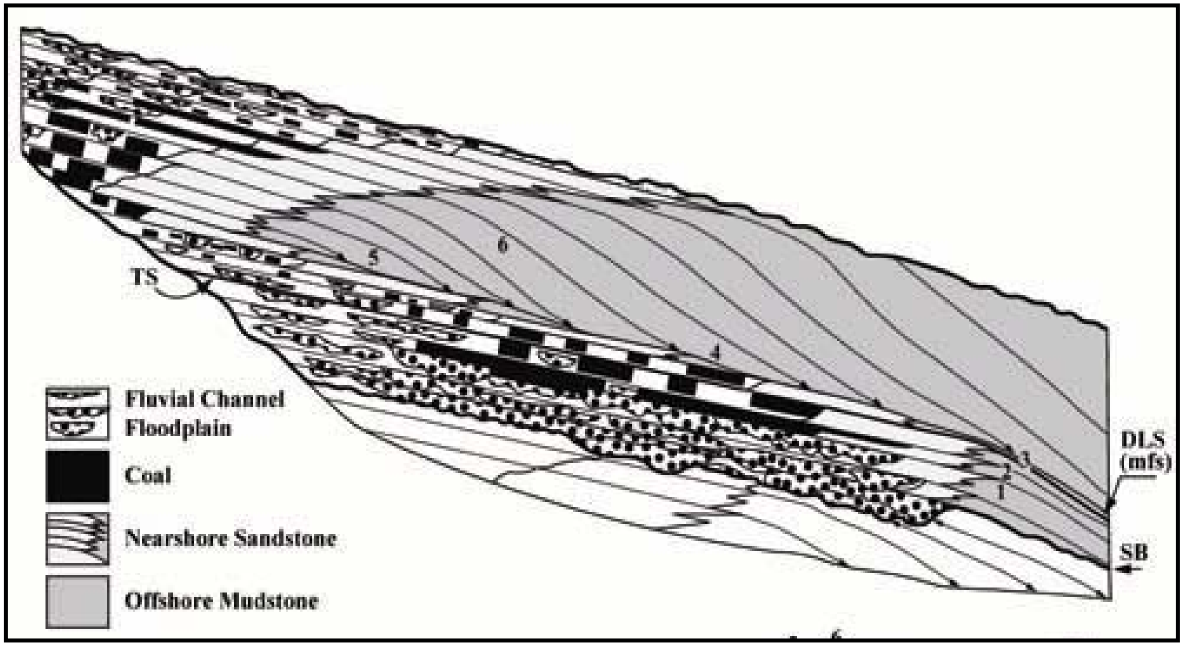
Component	UCG model predictions (percent)	Field measurements (percent)
Hydrogen	27.2	27.3
Carbon monoxide	13.0	6.4
Carbon dioxide	19.4	27.2
Methane	7.4	6.4
Water	33.0	33.0



Courtesy ErgoExergy

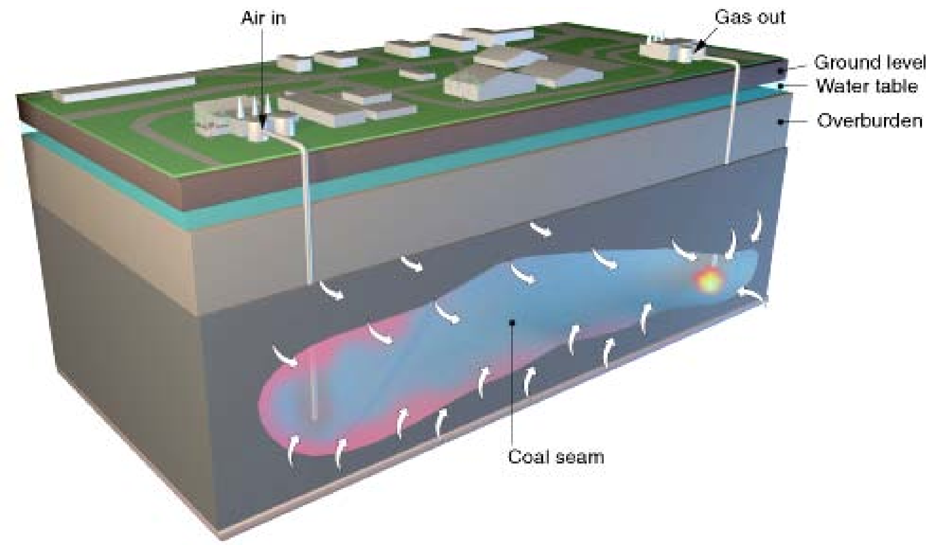
LLNL Focus: Criteria for site selection & planning

- **Geological Assessments**
  - Structural
  - Stratigraphic
  - Hydrologic
- **Contaminant Transport Prediction**
  - Potential contaminant types from coal and rock mineral compositions
  - Contaminant behavior under UCG burn and post-burn conditions



Stratigraphic category	Lateral Isolation	Overlying Unit Character	Relative Risk
1	Low	Sand-prone	High
2	Low	Shale-prone	Moderate
3	High	Shale-prone	Low
4	Moderate	Shale-prone	Moderate
5	Moderate	Sand-prone	High
6	Low	Sand-prone	High

UCG can and should always proceed in a way to manage and reduce groundwater risks



Pressure management

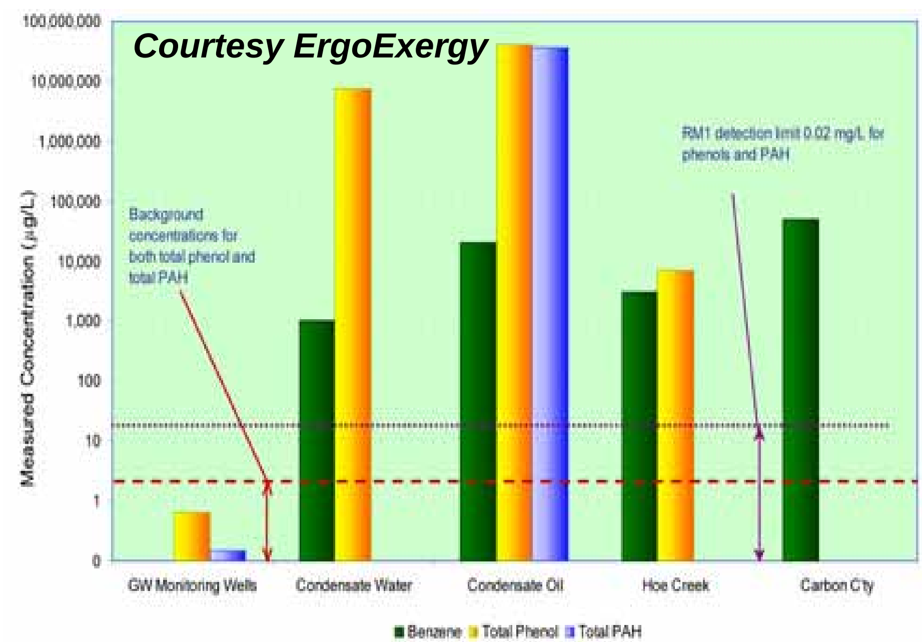
- Operate below hydrostatic pressure
- No flow of VOC out of cavity
- Validated at Chinchilla

Site selection

- Deeper sites (>200m; >500m preferred)
- More characterization of overburden
- Risk characterization

Regular monitoring

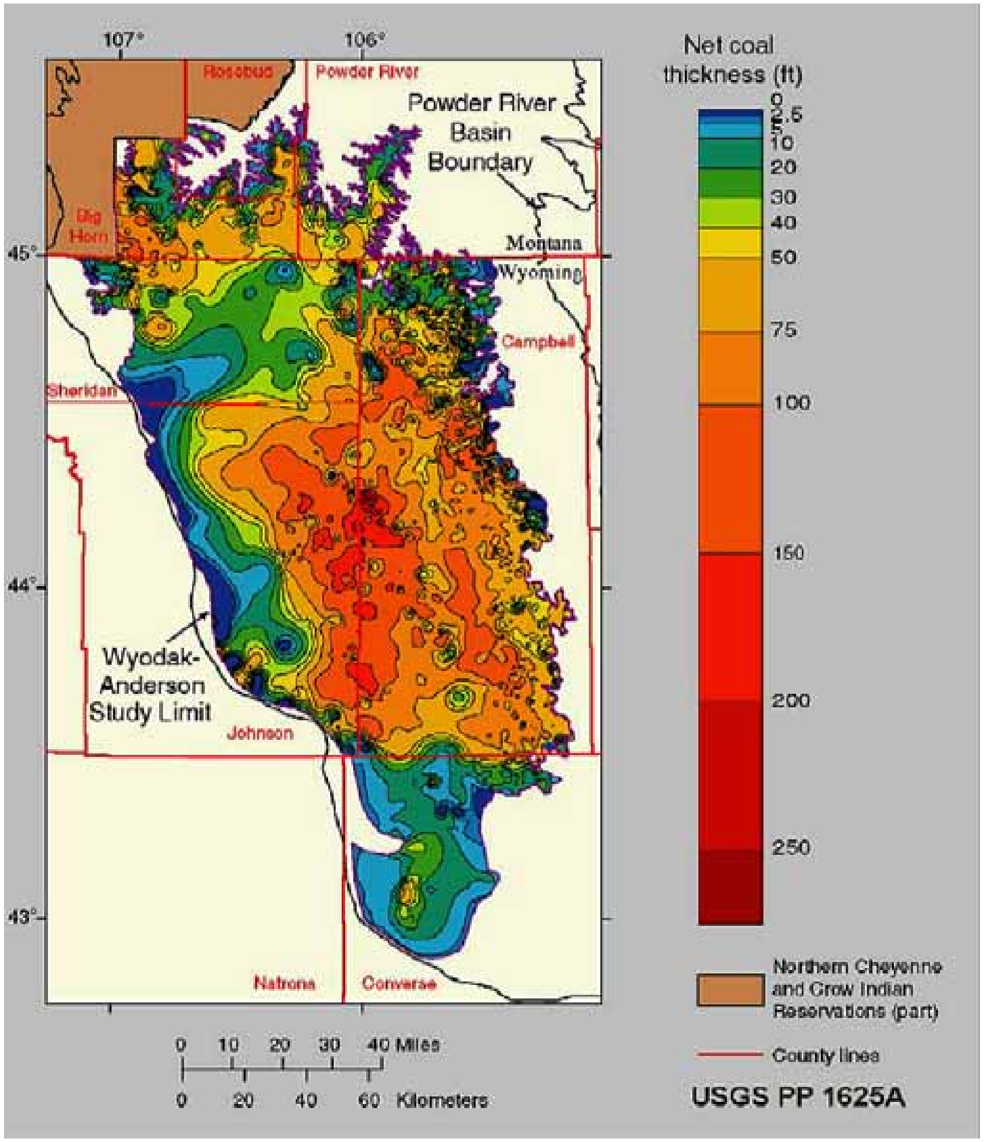
- Water chemistry, pressure
- Passive geophysics (ERT, microseismic)



Like all subsurface operations, hazards are real but can be readily managed

There are synergies between UCG and CBM development and production

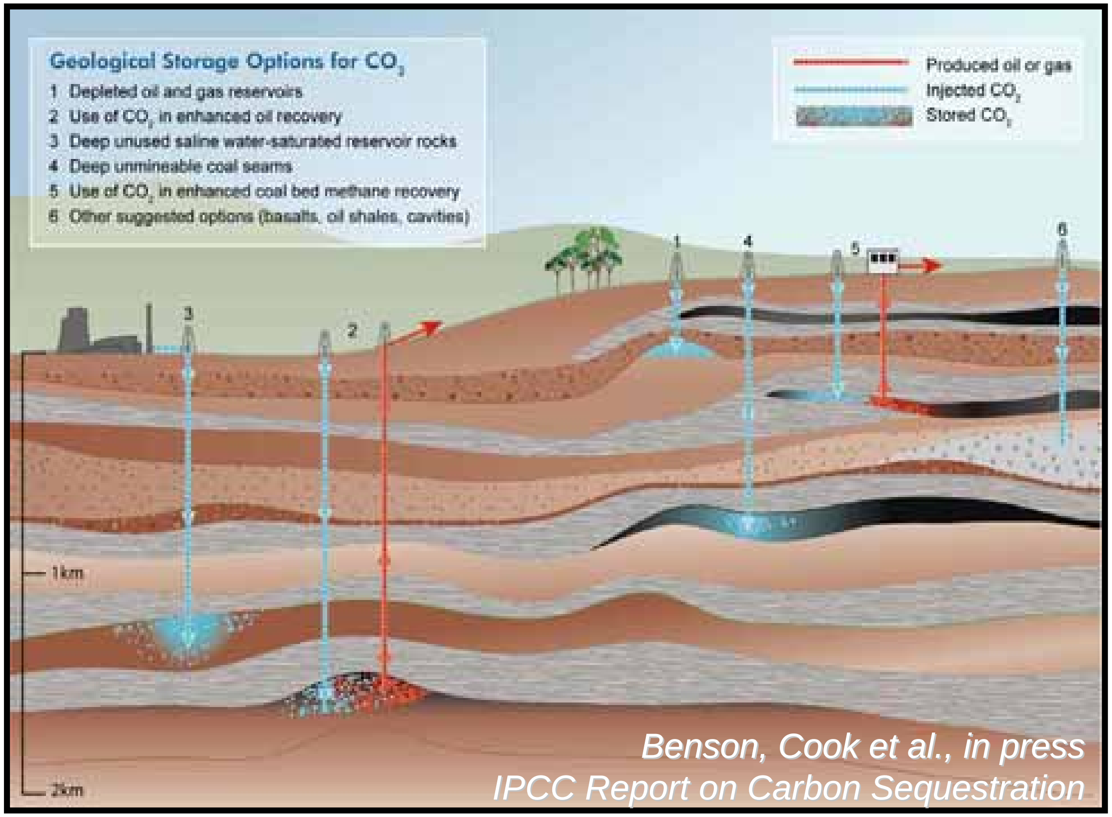
- Production elements at roughly same depths
- Detailed characterization of seam (drilling, production information)
- Production dewatering could lead to more process control
- Possibility to use existing wells as both injection and syngas production wells
- Land-use, management, regulatory issues convergent



Courtesy GasTech, Inc.

Carbon dioxide can be stored in geological targets, usually as a supercritical phase

Carbon capture & storage (CCS) has emerged as a new field for reducing greenhouse gas emissions, chiefly CO_2, through geological sequestration.



Benson, Cook et al., in press
IPCC Report on Carbon Sequestration

Saline Aquifers
Depleted Oil & Gas fields
(w/ or w/o EOR and EGR)
Unmineable Coal Seams
(w/ or w/o ECBM)

These formations are likely to be found near coal seams chosen for UCG

Carbon capture economics and coincidence of storage targets make an attractive carbon management package

Possible synergies between UCG and CCS

- Deeper sites = higher pressures

    Lower capture costs

- Low risk UCG sites are low-risk CCS sites
- Potential to double monitoring arrays

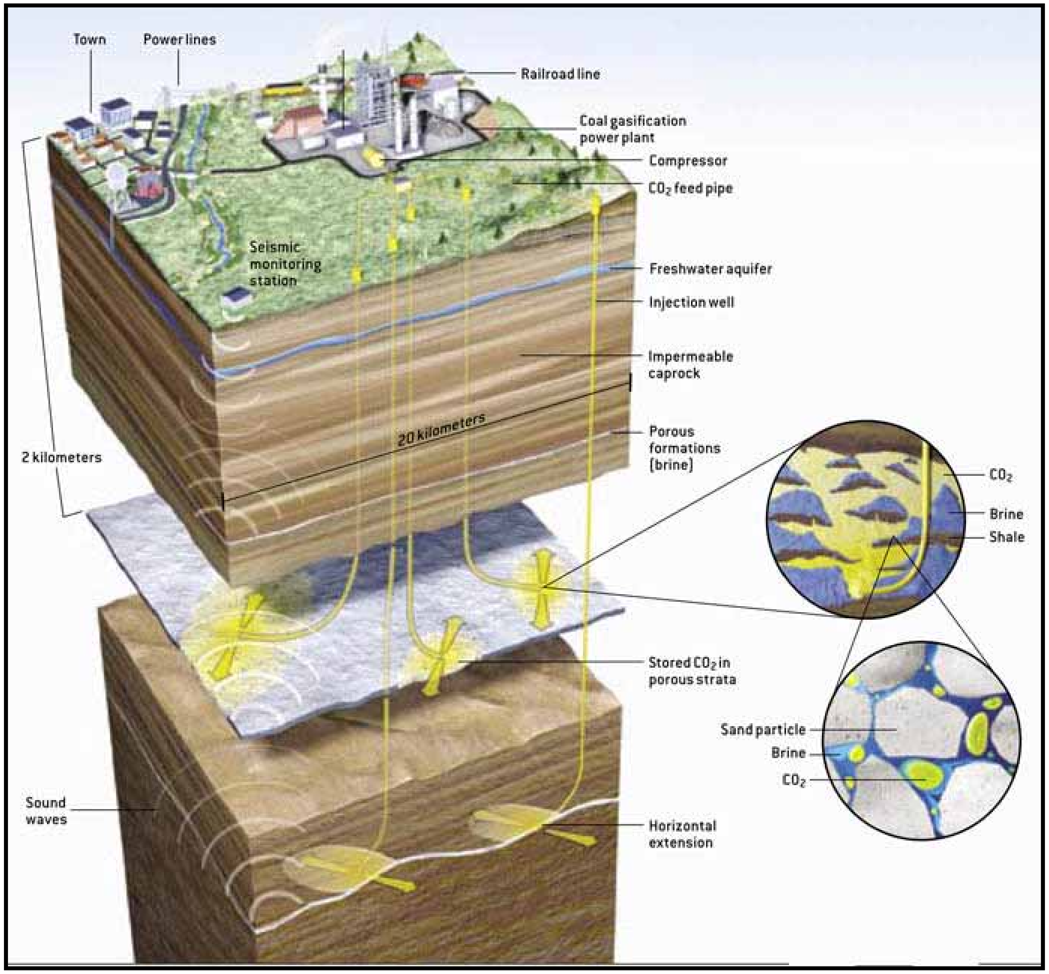
    Reduce operating costs

- Co-location of sites and facilities for conventional CCS

    Smaller footprint

- Potential for use of cavity as storage location

    This requires much more S&T

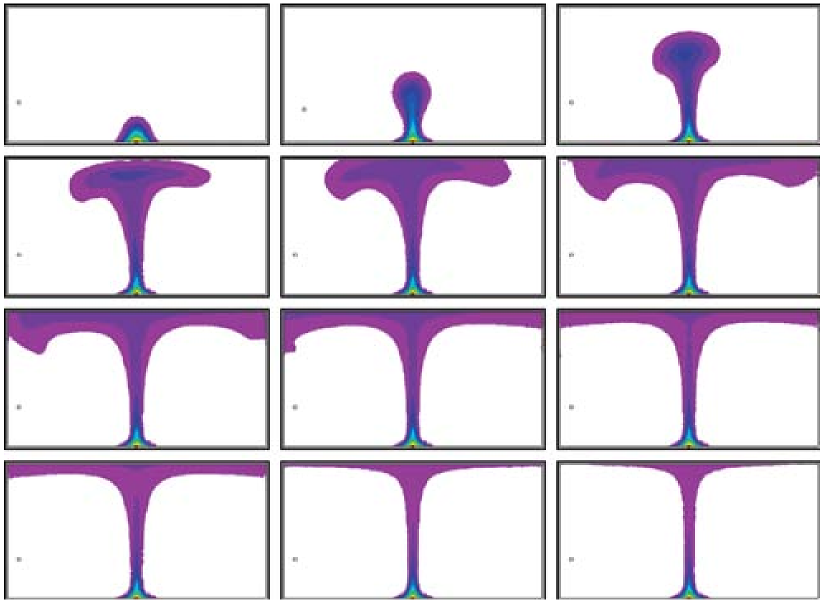


Both UCG and CCS are emerging technologies.
S&T development can help to enable and accelerate both

Technology gaps in UCG can be readily addressed through focused R&D initiatives

Simulation

- Integration of platforms (CFD, hydrologic, chemistry, surface facilities)
- Improved process models for syngas generation & production
- Improved process models for subsidence, env. fate and transport



Field pilots and demonstrations

- Application of a broad monitoring suite
- Validation of predictions; model improvements
- Economic characterizations with real facilities
- Ultimately, combined UCG + CCS

This RD&D agenda is fairly simple, and could be readily addressed through collaborative research programs

Conclusions regarding UCG

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Disclaimer and Auspices Statements

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

DOE & LLNL have been active in UCG for over three decades

- Invented the CRIP (controlled retractable injection point) process (1974-1985)
- Conducted a number of field tests (Hoe Creek, Hanna, Centralia)
- Developed cavity growth models (Thorseness and Britten, 1989)
- Developed a CFD-based model of the UCG process and integrated it with Aspen Plus (Wallman 2004)
- Currently expanding the CFD model to include additional phenomenology
- Developed a large suite of tools for environmental assessment
- Developed methodologies for process control monitoring
- Applied carbon management and CO_2 sequestration expertise to UCG (Blinderman & Friedmann, 2006)