DOE/LLNL Activities in Underground Coal Gasification

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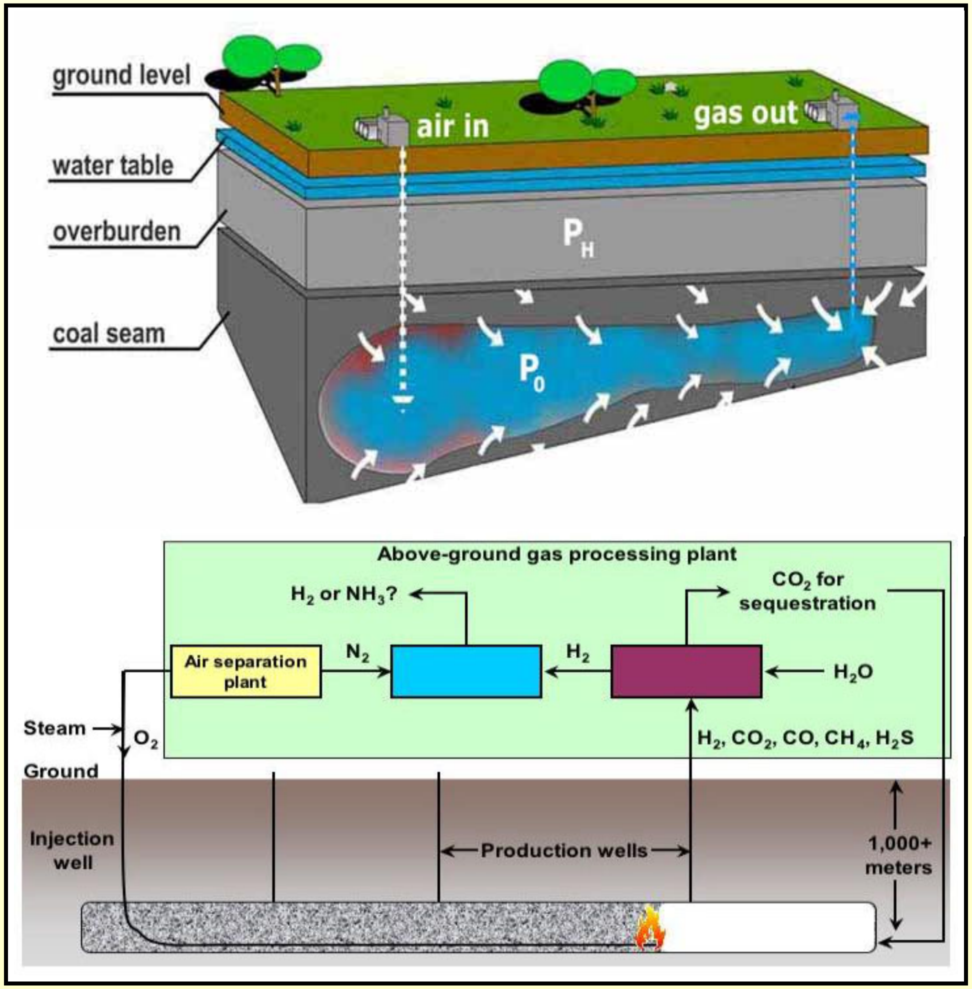
Underground coal gasification produces syngas with low capital and low operating cost

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

- **No mining; no ash management**
- **No gasifier purchase or operation**
- **High pressure syngas stream = low-cost partial decarbonization**
- **No particulates or NO_x; sulfur management straightforward**
- **Good coincidence between CCS and UCG sites**



UCG is important to India for several reasons

- India has approximately 467 bt of possible coal reserves, nearly 66% of which are potential candidates for UCG, located at deep to intermediate depths

- Indian coals contain a high fraction of ash (30-45%), most of which will stay underground with UCG. As a result, very little solid waste is produced.

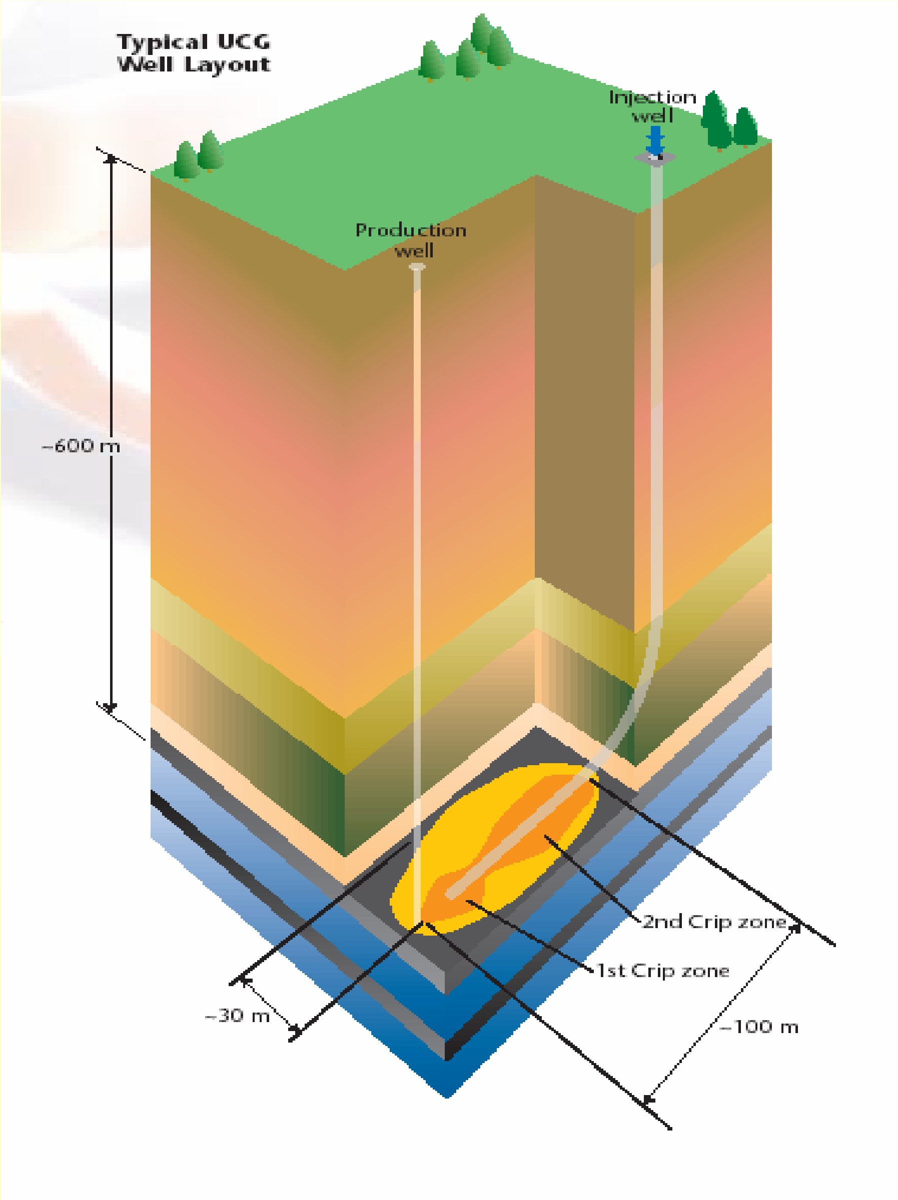
- UCG readily lends itself to CO_2 management (reinjection of CO_2)

- The syngas produced by UCG can be used for power production as well as a chemical feedstock

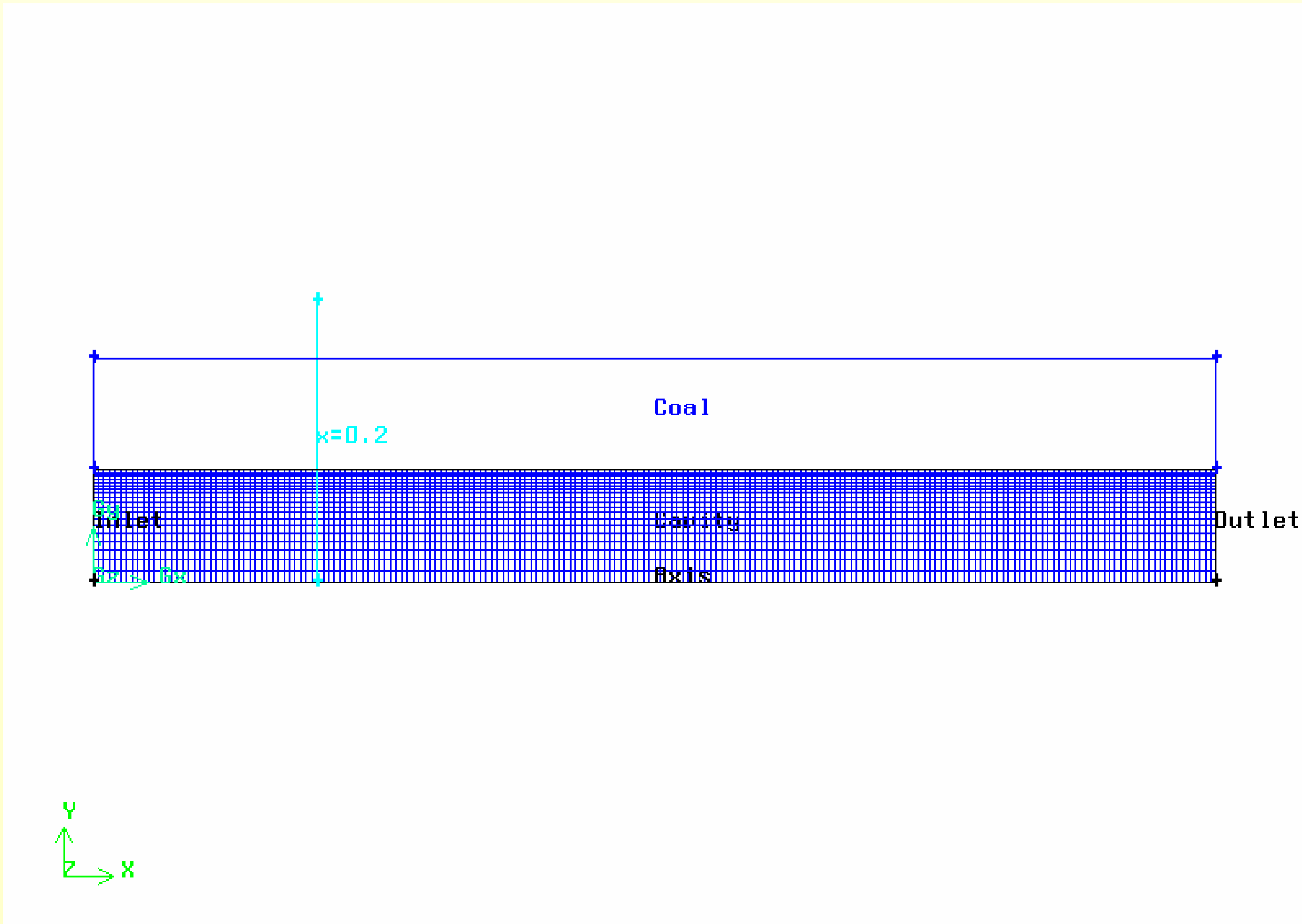
DOE/LLNL has been active in UCG for over three decades

- Invented the CRIP (controlled retractable injection point) process (mid 1970, early 1980)
- 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

CRIP implementation



Features of the LLNL CFD Model - I



Features of the LLNL CFD Model - II

- **Cylindrically symmetric cavity**
- **Considers influx of water and coal pyrolysis**
- **1-cm thermal wave ahead of surface reactions**
- **Coal = $CH_{0.08}$**
- **WGS shift reaction and coal gasification reactions are considered to be volumetric, but known kinetics are used**
- **Radiation effects are ignored**

The simple model works

Typical UCG gas compositions adjusted to 33 mol% water content.

Component	UCG Model	Field Measurement(1)
H_2	27.2	27.3
CH_4	7.4	6.4
H_2O	33.0	33.0

The simple model works ... for some variables!

Typical UCG gas compositions adjusted to 33 mol% water content.

Component	UCG Model	Field Measurement(1)
H_2	27.2	27.3
CO	13.0	6.4
CO_2	19.4	27.2
CH_4	7.4	6.4
H_2O	33.0	33.0

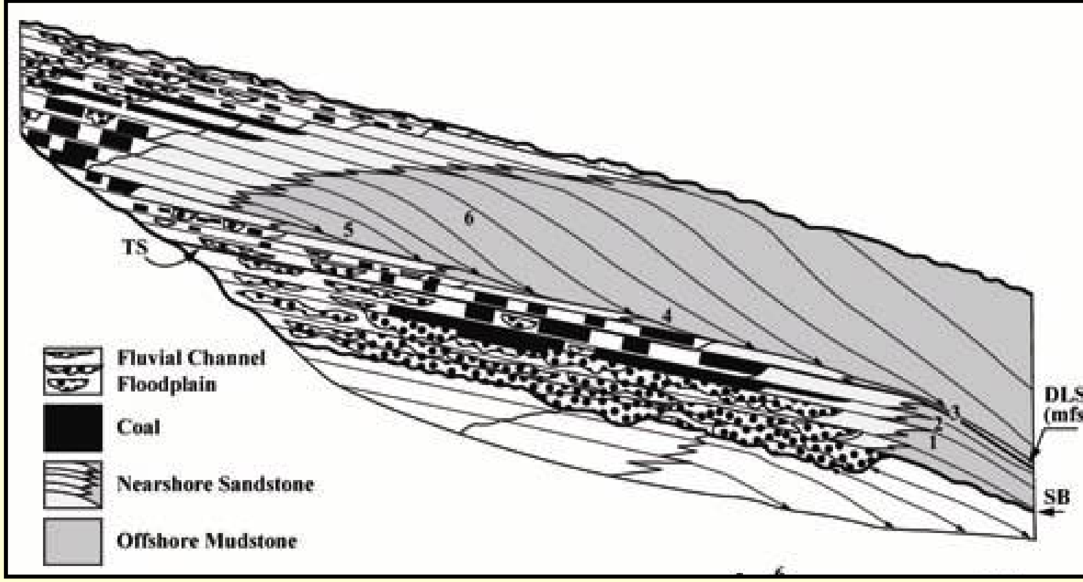
The model needs improvement

- Steady-state → Dynamic
- Include radiation
- Treat some reactions as surface reactions
- Need improvements in the treatment of the porous zone
- Integrate it with environmental impact models) and surface facilities

DOE/LLNL has expertise in environmental assessment of and planning for UCG - I

LLNL Areas of Environmental Expertise in UCG

- Geological Assessments
  - Structural
  - Stratigraphic
  - Hydrologic
- Risk Assessment
  - Environmental
  - Health
- Environmental Remediation
  - Bioattenuation
  - Treatment and monitoring

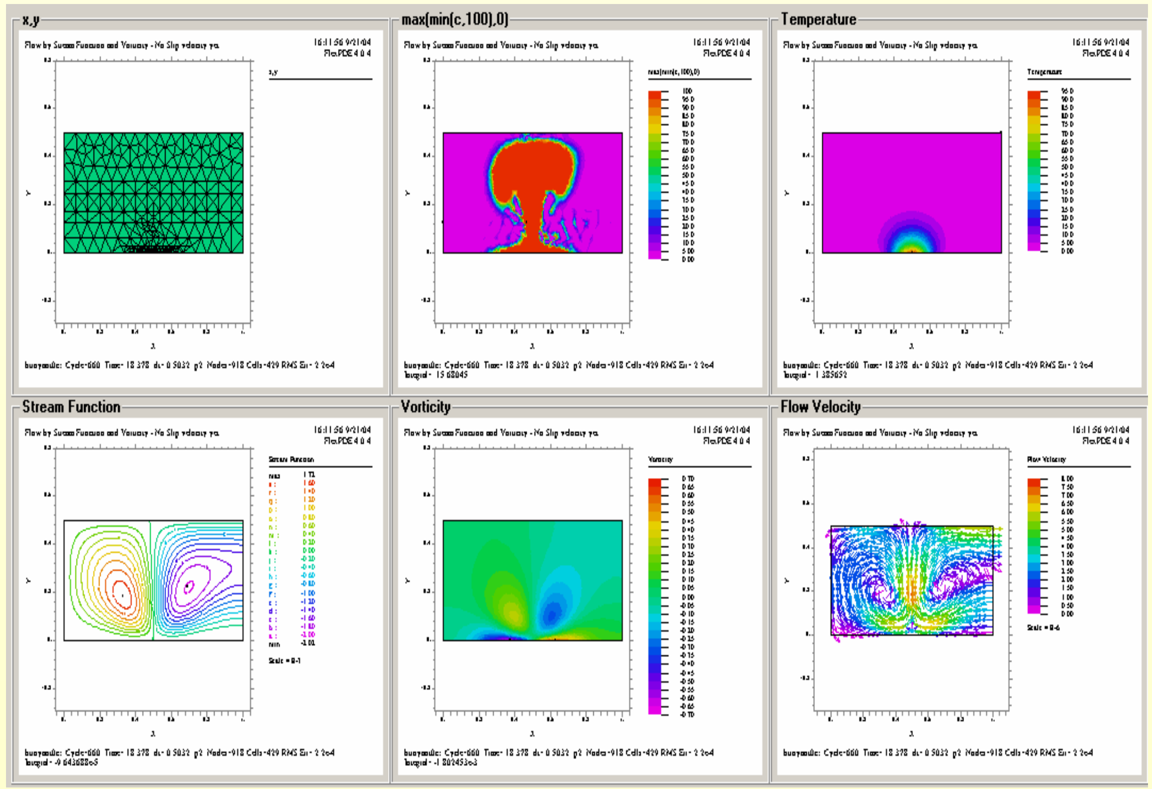


Stratigraphic category	Lateral Isolation	Overlying Unit Character	Relative Risk
1	Low	Sand-prone	High
2	Low	Shale-prone	Moderate
3	High	Shale-prone	Low
4	Moderate	Shale-prone	Moderate
5	Moderate	Sand-prone	High
6	Low	Sand-prone	High

DOE/LLNL has expertise in environmental assessment of and planning for UCG - II

LLNL Areas of Environmental Expertise in UCG

- Geochemistry
  - Laboratory testing,
  - Modeling
  - Analytical support
- Geomechanics
  - Laboratory testing
  - Modeling
- Carbon Management
  - Site selection
  - CO_2 storage options
  - Capture technology and economics



Carbon capture and storage (CCS) has emerged as a new field aimed at reducing greenhouse gas emissions, chiefly CO_2, through geological sequestration. LLNL's carbon management program has led investigations into safe, low-cost separation and capture of CO_2 from UCG syngas and storage in neighboring formations.

Environmental assessment models need to be integrated with process models

- **Three principal elements of environmental threats posed by UCG:**
  - **the generation of contaminants within the burn chamber,**
  - **enhanced vertical hydraulic conductivity of the rock matrix above the burn chamber as a result of collapse and fracturing, and**
  - **buoyancy-driven upward flow of groundwater in the vicinity of the burn chamber toward potable water resources at shallower depths.**
- **The complexity of UCG systems requires use of hydrological, geochemical and geomechanical models**
- **The CFD process models and the Aspen Plus models need to be integrated with the environmental models for the design, operation and control of a UCG process**

What next?

- Visit by Indian delegation to US UCG sites and National Laboratories: 2Q 2006
- Joint UCG workshop in India: 4Q 2006
- Identify a few potential UCG sites in India: 1Q 2007
- Investigate their suitability for
  - sustained production
  - environmental effects avoidance/mitigation 2Q 2007
- Select 1-2 sites for further in-depth study: 2Q 2007
  - develop environmental assessment
  - develop process models, both under- and above- ground
  - perform economic analysis

Backup Slides

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Lessons from Hoe Creek

possible mechanisms for contamination from UCG:

- **Hot product gases from gasification and pyrolysis escape into surrounding coal and then on to connected aquifers**
- **After the completion of gasification, the gasification cavity is filled with water, and sorbed compounds are leached out**
- **Gasification cavity collapse may connect the coal aquifer to a previously unconnected aquifer**