PURDUE UNIVERSITY
Discovery Park Energy Center

# The Potential for Underground Coal Gasification in Indiana

## Phase I Report to CCTR

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# Outline

- Analysis of UCG current state of science and technology
- Determination of criteria for site selection
- Summary and recommendations

# 1. Analysis of UCG Current State of Science and Technology

- USSR (before 1991), Russia, Ukraine, Uzbekistan (after 1991)
- United States
- Western Europe
- Canada
- Australia
- South Africa
- China
- New Zealand, India, Japan, …
- Analysis of patents
- Comparison of alternative technologies

# USSR; now Russia, Ukraine, Uzbekistan

- In the 1960s, five UCG gas production stations were operating; one plant is still in operation after ~50 years
- Recent monographs (2004, 2006) review old Soviet UCG activity and include information on recent work in Russia
- Old Soviet technology
  - Linkage techniques (reverse combustion, hydraulic fracturing)
  - Empirical formulas and mathematical models
  - Rock movement, hydrogeology
  - Ecological monitoring
- New Russian technology
  - Accounts for US and Western European experience
  - New applications

# United States

- More than 30 experiments between 1972 and 1989
- Continuous Retraction Injection Point (CRIP) process

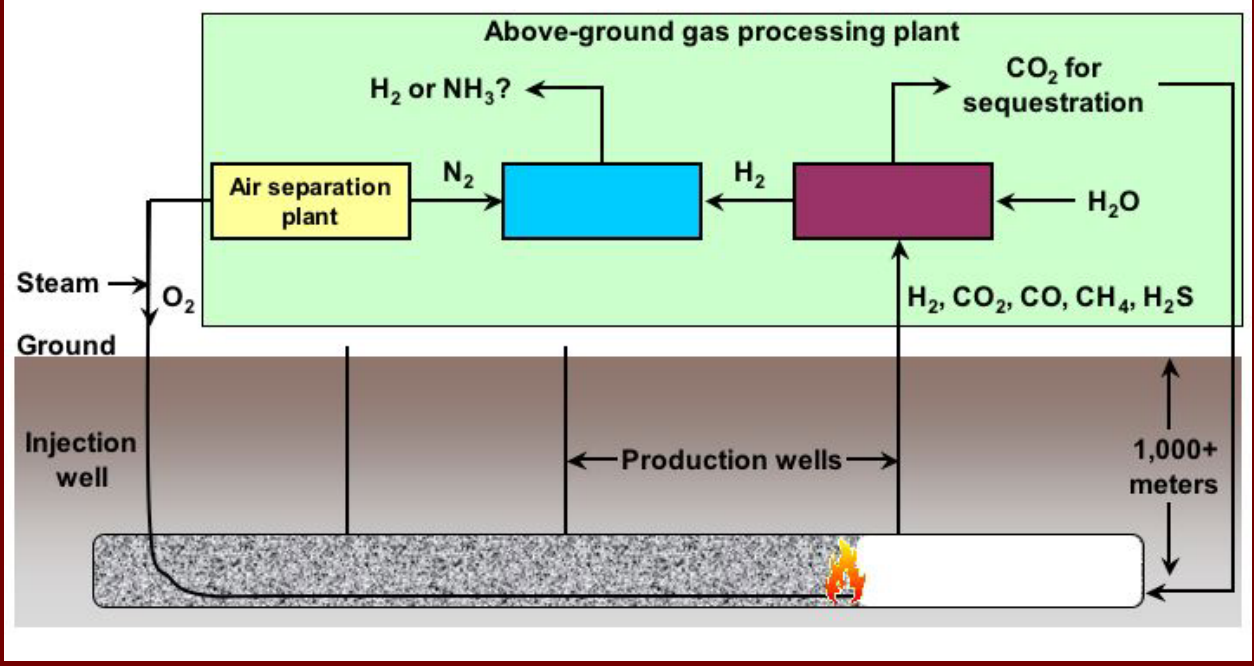



Image: LLNL

# Western Europe

- A number of UCG tests have been carried
- A significant difference of these tests is the large depth of coal seams (600-1200 m)
- In 1992-1999, a UCG project was conducted by Spain, the UK and Belgium at "El Tremedal" (Spain)
- In 2004, DTI (UK) identified UCG as one of the potential future technologies for the development of the UK's large coal reserves

# Canada

- Ergo Exergy Technologies Inc (Montreal) is providing UCG technology to several customers in different countries
- They use εUCG™ technology, apparently based on the old Soviet UCG technology; may include recent approaches developed in Russia
- Laurus Energy is developing the first commercial project, based on εUCG™ technology, in Canada

# Australia

- Linc Energy Ltd conducted a UCG trial at Chinchilla, using Ergo Exergy's technology
  - The Chinchilla project (1999-2003) has demonstrated the feasibility to control UCG process and gasified 35,000 tons of coal, with no environmental issues
  - Since 2006 co-operate with the Skochinsky Institute of Mining in Moscow; acquired a 60% controlling interest in Yerostigaz, which owns the UCG site in Angren (Uzbekistan)
- Cougar Energy Ltd plans the pilot burn for a 400MW combined cycle power project
- Carbon Energy PL plans a 100-day field trial to show commercial feasibility of the CRIP UCG process

# South Africa

- Eskom, a coal-fired utility, is investigating UCG at its Majuba 4,100 MW power plant
- Ergo Exergy provides the technology to build and operate a UCG pilot which was ignited in 2007
- The Eskom Pilot Project will be expanded in a staged manner, based on the success of the each preceding phase
  - The project currently generates ~3,000 $m^3$/hr of flared gas
  - Volumes will increase to 70,000 $m^3$/hr early next year and be piped to the station before eventually rising to 250,000 $m^3$/hr
  - Some 3.5 million $m^3$/hr will be supplied to the power station at full production that is anticipated around 2012

# China

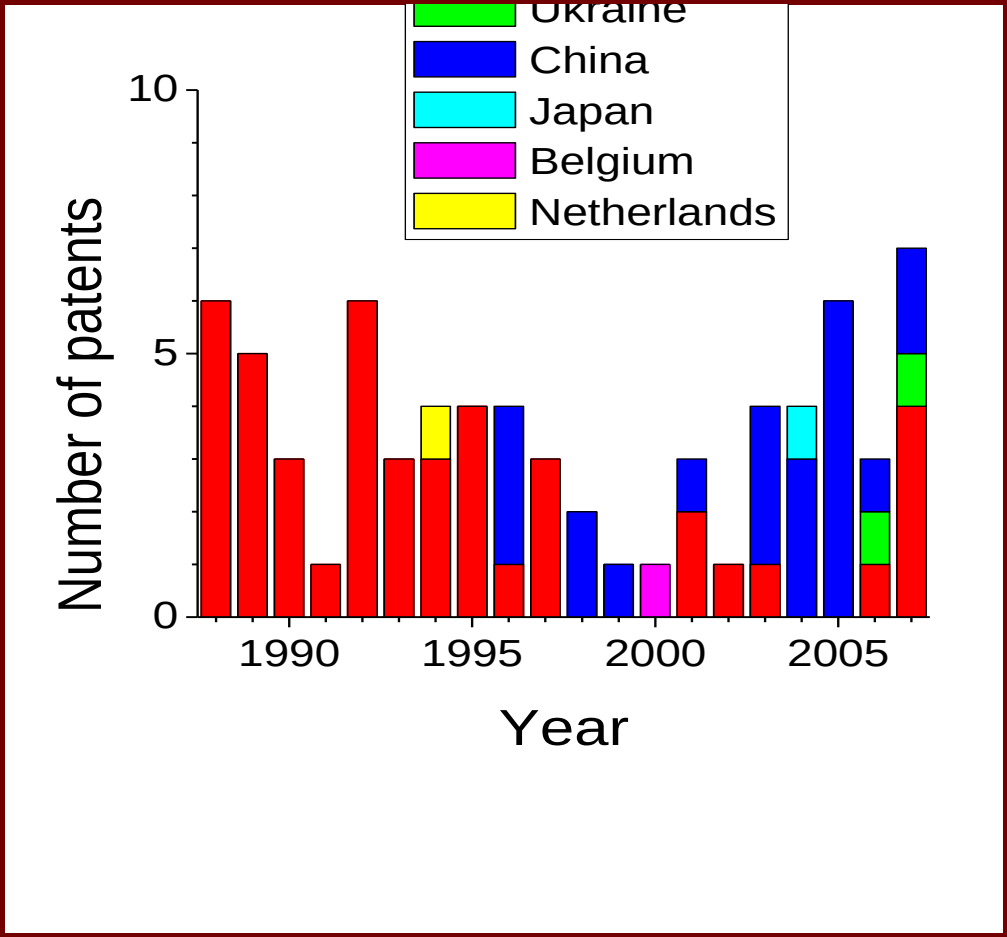
- Since the late 1980s, 16 UCG trials have been carried out or are currently operating
- Chinese UCG trials utilize abandoned coal mines
- Commercialization
  - XinWen coal mining group has six reactors with syngas used for cooking and heating
  - A project in Shanxi Province uses UCG gas for the production of ammonia and hydrogen
  - Hebei Xin'ao Group is constructing a liquid fuel production facility fed by UCG ($112 million); 100,000 ton/yr of methanol and generate 32.4 million kWh/yr

# New Zealand, India, Japan, …

- Solid Energy New Zealand Ltd, an energy company founded on mining coal in difficult conditions, plans to use Ergo Exergy's εUCG™ technology for low cost access to unminable coal
- The Oil and Natural Gas Corporation Ltd (ONGC) and the Gas Authority of India Ltd (GAIL) plans pilot projects with Skochinsky Institute of Mining and Ergo Exergy
- AE Coal Technologies India Pvt Ltd plans UCG projects
- The University of Tokyo and coal companies have been conducting technical and economic studies of UCG on a small scale and are planning a trial in the near future

# Analysis of patents

- Patents from 1988 to 2008
  - Russia: 44
  - China: 22
  - North America: 0



# Comparison of alternative technologies

- The main controversy in UCG is related to the methods for linking injection and production wells
  - Hydraulic fracturing and reverse combustion (USSR)
  - Directional drilling and CRIP (US, Western Europe)
- Kreinin (2004) claims that new Russian technology combines all methods

# 2. Determination of Criteria for Site Selection

- Thickness of coal seam
- Depth of coal seam
- Coal rank and other properties
- Dip of coal seam
- Groundwater
- Amount of coal
- Land-use restrictions
- Noise

# Thickness of coal seam

| Thickness | Suitability |
|---|---|
| > 2.0 m | high |
| 1.5 – 2.0 m | medium |
| 1.0 – 1.5 m | low |
| < 1.0 m | unacceptable |

- Of the seven major coal seams present in Indiana, only the Seelyville and Springfield Coals have a significant quantity of sufficiently thick sites (>1.5 m). Thus, the selection process will focus on these two coal beds only.

# Depth of coal seam

| Depth | Suitability |
|---|---|
| > 200 m | high |
| 60-200 m<br>high yield strength of overburden rocks | medium |
| 60-200 m<br>low yield strength of overburden rocks | low |
| < 60 m | unacceptable |

- If potential UCG sites are found at different depths, further analysis should be made: tradeoff between the higher cost of deeper wells and the advantages of UCG at larger depth

# Coal rank and other properties

- Low rank, high volatile, non-caking bituminous coals are preferable. Indiana coals are characterized by high-volatile bituminous rank and have relatively high heating value, which makes them attractive for UCG
- It is difficult to use porosity and permeability of the coal seam as a criterion because of the scarcity of data
- It is often recommended that coals should not exhibit significant swelling upon heating, but the FSU methods demonstrated minimum sensitivity to coal swelling

# Dip of coal seam

- Shallow dipping seams are preferable (0-20 degrees)
- Indiana coals place within this range
- UCG has been successfully carried out in steeply dipping seams, thus dip is not an important criterion for selecting UCG sites

# Groundwater

- It is desirable to select coals with relatively low moisture content, located far from abundant water reserves
- It is recommended to use coal seams with no overlying aquifers within a distance of 25 times the seam height, to reduce the potential risk of contamination

# Amount of coal

- The UCG applications can be of different scale:
  - mobile units that could provide gas in agricultural areas
  - large power and chemical plants producing hundreds and thousands MW of electrical energy and vast amounts of hydrocarbon-based products
- Evaluation of potential sites must include the determination of the available amount of coal in conjunction with potential applications

# Land-use restrictions

- There is no indication that UCG should be further from towns, roads and other objects than underground mines, assuming that the process design and environmental monitoring ensure ecological safety
- Thus, the land-use restrictions for underground mining determined by IGS can be applied to potential UCG sites

# Noise

- The cumulative effects of noise levels resulting from UCG operations are not expected to be noticeable to residents or visitors within the area except during construction activities or around compressor facilities

# Summary and Recommendations

- UCG technology has a potential to grow and replace/complement traditional methods for coal mining and gasification
- New commercial UCG projects use techniques and approaches developed in the USSR and later in Russia, as well as in the United States, primarily through involvement of experts from either ErgoExergy or Russian organizations
- Selection of the best UCG technology is a complex process, and the properties of the UCG site must be taken into consideration

# Summary and Recommendations, cnt'd

- The criteria for selecting UCG sites in Indiana have been formulated
  - Focus on the Seelyville and Springfield Coal Members
  - The coal seam thickness is the first criterion
  - Then depth and other criteria will be considered
- After selection of potential UCG sites, additional analysis will be required, which may include estimates of
  - composition and heating value of the product gas
  - coal availability for specific applications
- An economic analysis will need to also be conducted; this, however, is beyond the scope of the current project

# Project Phases

- Phase 1 (completed August 31, 2008)
  - Analysis of UCG current state of the science and technology (globally) and determination of criteria for selecting UCG locations in Indiana
  - Responsibility: Purdue
- Phase 2 (by November 30, 2008)
  - Determination of suitable UCG locations in Indiana
  - Responsibility: IGS
- Phase 3 (by January 15, 2009)
  - Selection of the most promising UCG locations
  - Recommendations for future work
  - Responsibility: Purdue and IGS