Underground Coal Gasification (UCG)

CCTR Basic Facts File # 12

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October 2008

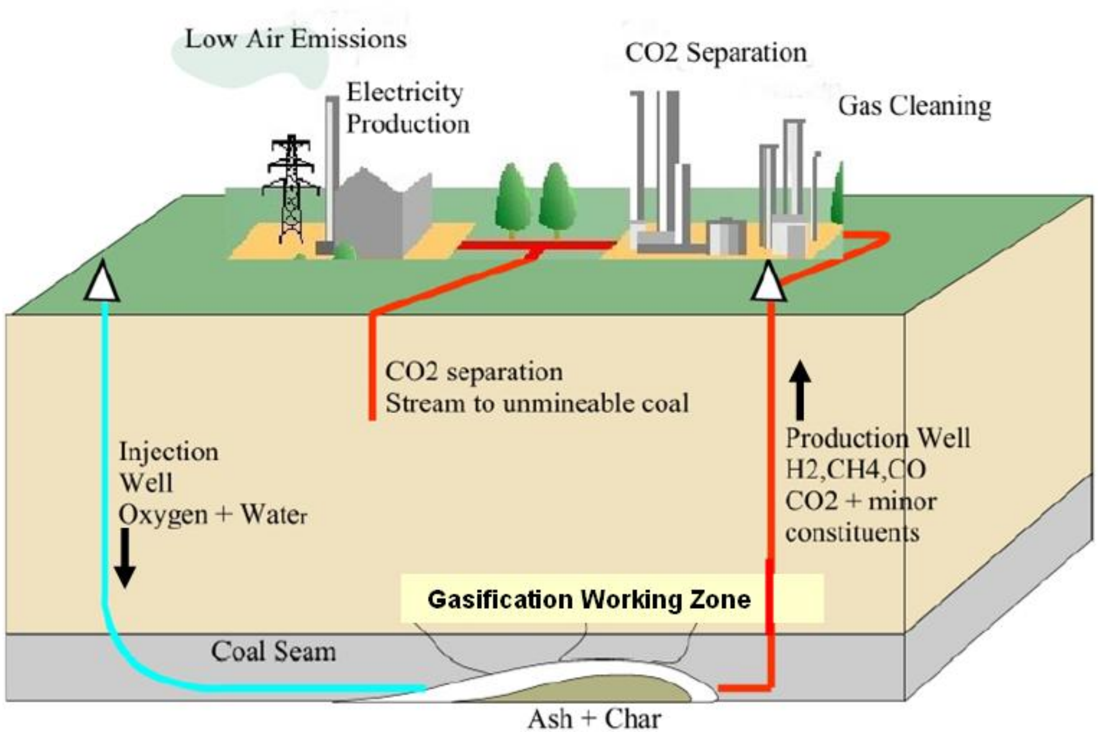
UCG Essentials

Underground Coal Gasification (UCG) converts coal into a gaseous form (syngas) through the **same chemical reactions** that occur in surface gasifiers

The **economics of UCG are very promising**. Capital expenses are considerably less than surface gasification because the purchase of a gasifier is not needed

UCG makes it economically possible **to obtain energy from 300% more coal** than is recoverable with current technology

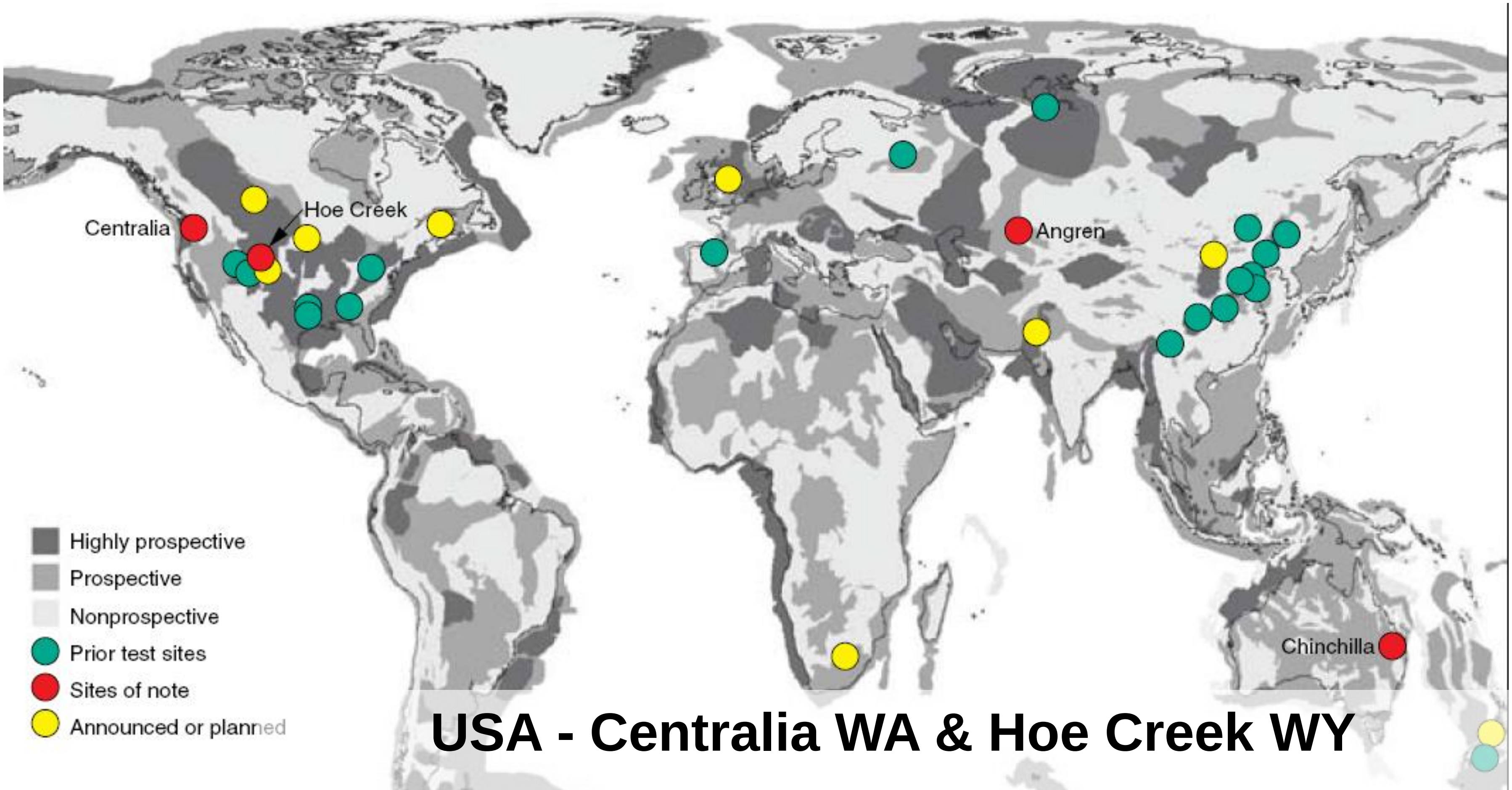
A UCG Production Facility



Air is injected into the cavity, water enters from surrounding rock & partial combustion with gasification take place at the coal seam face following ignition. The resulting high pressure syngas stream is returned to the surface, where the gas is separated & contaminants are removed

"Best Practices in Underground Coal Gasification", E.Burton, J.Friedman, R. Upadhye, Lawrence Livermore Nat. Lab., DOE Contract No. W-7405-Eng-48

Worldwide UCG Sites



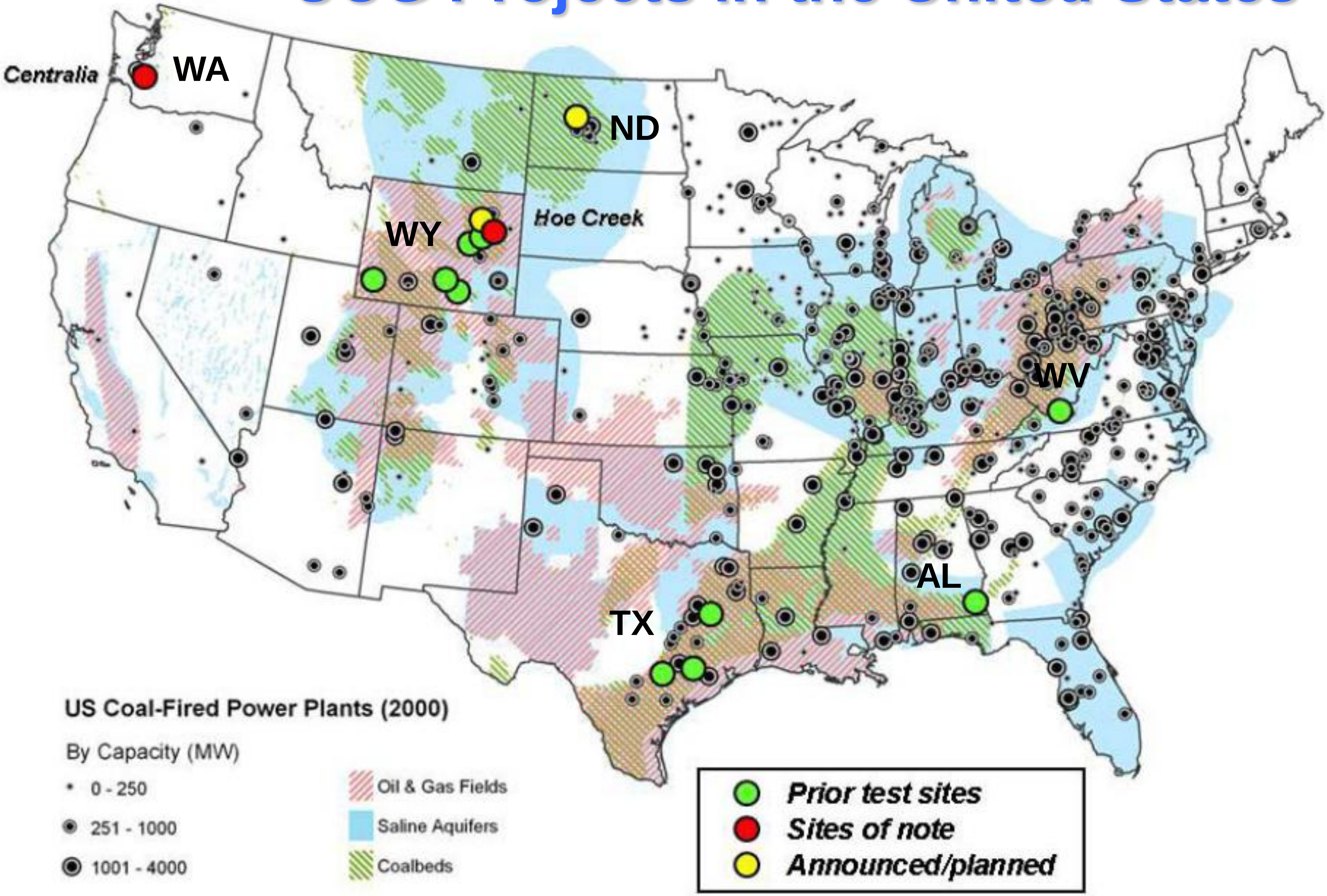
USA - Centralia WA & Hoe Creek WY

Australia, China, India, South Africa, Uzbekistan

Grey areas show potential areas for geological carbon storage

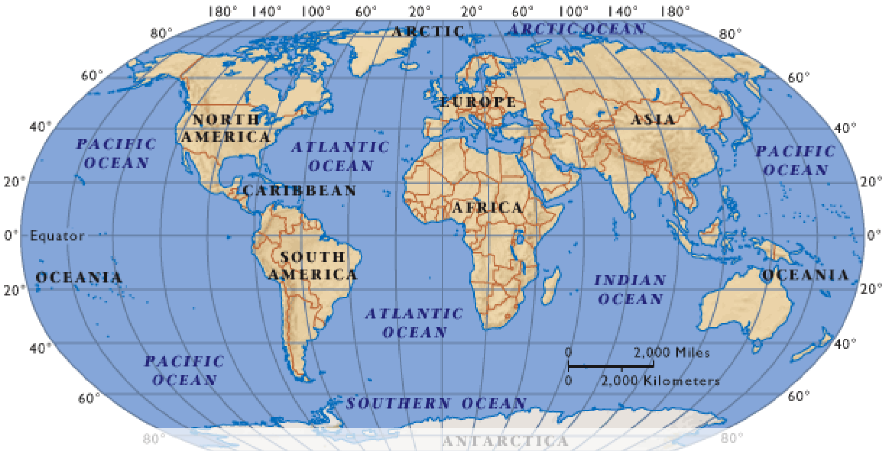
Source: “Fire in the Hole”, Lawrence Livermore National Laboratory, April 2007

UCG Projects in the United States



“Best Practices in Underground Coal Gasification”, E.Burton, J.Friedman, R. Upadhye, Lawrence Livermore Nat. Lab., DOE Contract No. W-7405-Eng-48

UCG Trials in US & World-Wide



Testing UCG in the **US from 1973 to 1989**. The Lawrence Livermore National Laboratory conducted tests at the Hoe Creek site in Wyoming

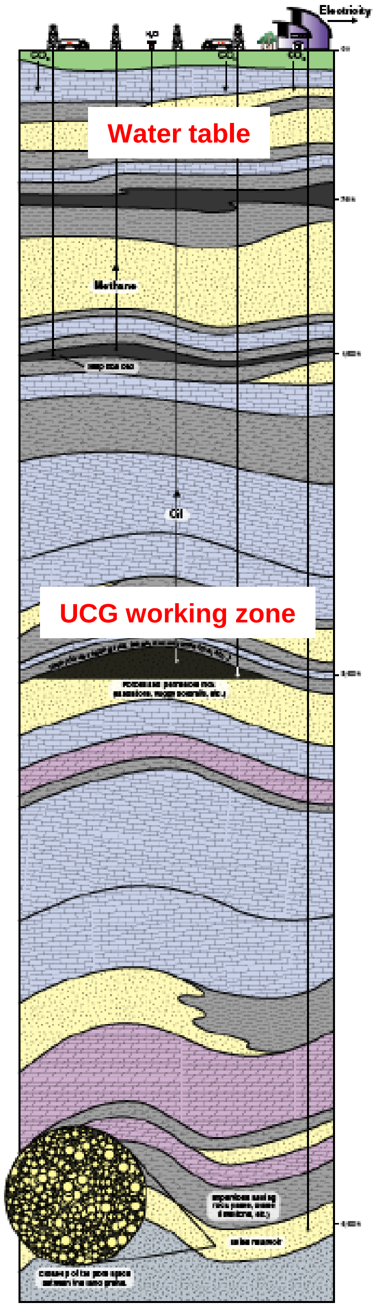
The **United Kingdom started UCG testing** in 1912 & the **Former Soviet Union** in 1928. **China** has been conducting tests since the 1980s **& Australia** since the 1990s

European UCG testing has taken place in Belgium (1982-1984), France (1983-1984), Spain (1992-1999), & United Kingdom (1999-2000)

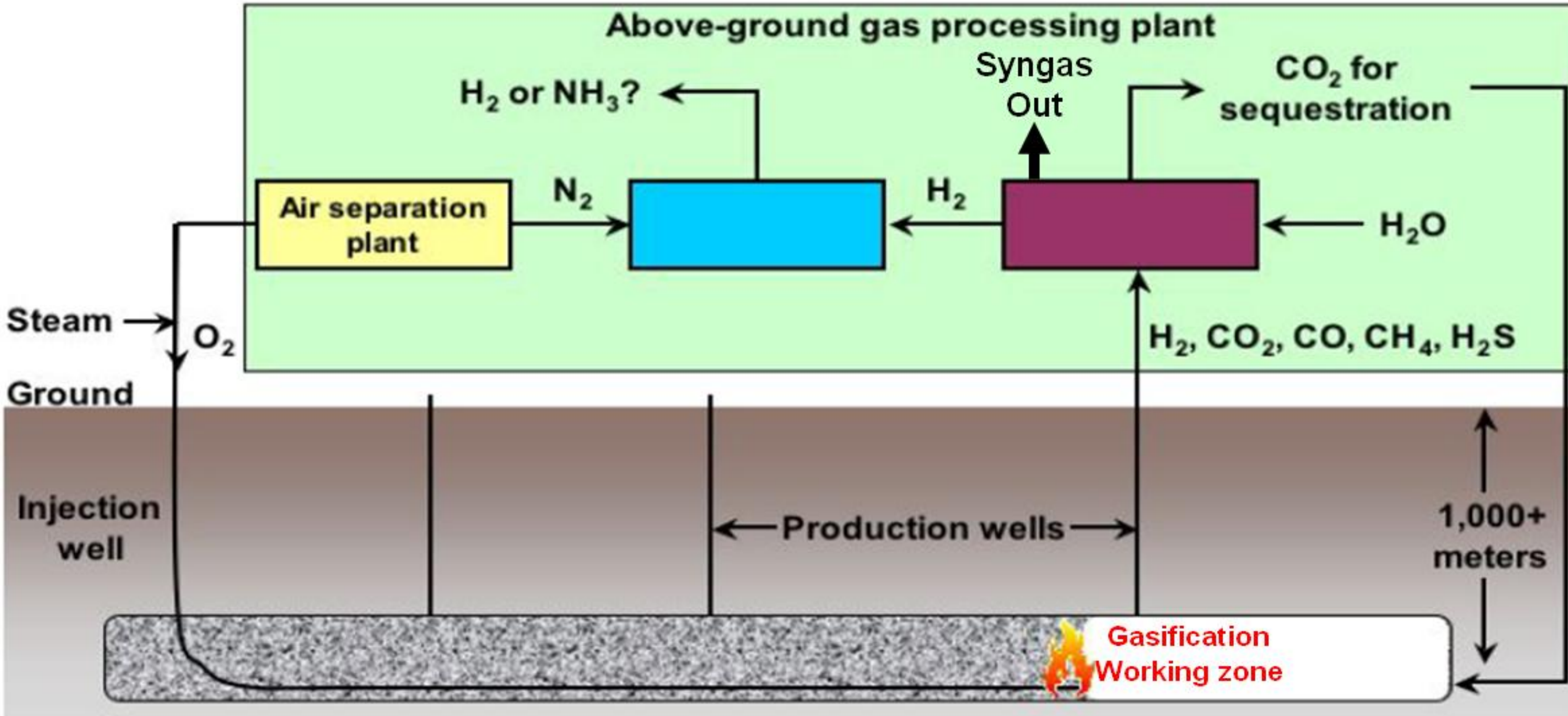
UCG Site Criteria

Criteria for a suitable UCG site location:

- Geology is key to **safeguard environment**
- Geologically **isolated deep beds**
- Deep aquifers should consist of **saline, non-potable water & have stratigraphic seals**
- Structural integrity & **no possibility of cavity roof caving in**



Schematic of the Continuous Retraction Injection Point Process



Most important is the **method for establishing a channel** between the injection & production wells

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Fundamental Coal Gasification Reactions

Most important reaction (1)
Syngas from H_2 and CO

Methane formation reactions (3)&(4)

Reaction		Enthalpy
(1)	Heterogeneous water-gas shift reaction $C + H_2O = H_2 + CO$	$\Delta H = +118.5$ kJ mol-1
(2)	Shift conversion $CO + H_2O = H_2 + CO_2$	$\Delta H = -42.3$ kJ mol-1
(3)	Methanation $CO + 3H_2 = CH_4 + H_2O$	$\Delta H = -206.0$ kJ mol-1
(4)	Hydrogenating gasification $C + 2H_2 = CH_4$	$\Delta H = -87.5$ kJ mol-1
(5)	Partial oxidation $C + 1/2O_2 = CO$	$\Delta H = -123.1$ kJ mol-1
(6)	Oxidation $C + O_2 = CO_2$	$\Delta H = -406.0$ kJ mol-1
(7)	Boudouard reaction $C + CO_2 = 2CO$	$\Delta H = +159.9$ kJ mol-1

Heat

Two oxidation reactions (5)&(6) provide heat to (1)

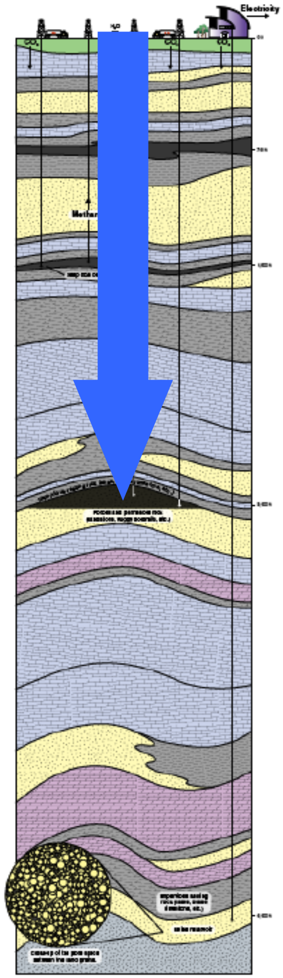
Ruprecht, etal., 1988

UCG Site Selection Factor
Depth of Coal Seam

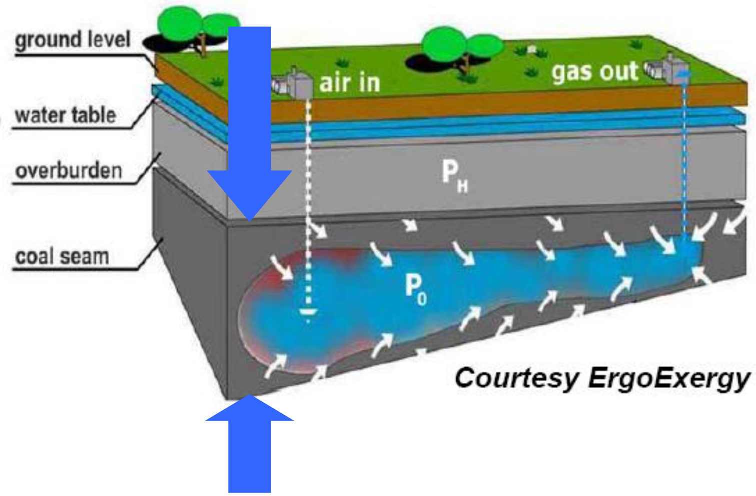
Deeper seams require **guided drilling technology** to initiate a well at the surface that is deviated to intercept & follow a coal seam & **establish a link between injection & production wells (**incurs higher drilling costs)

Deeper seams are less likely to be linked with potable aquifers, thus **avoiding drinkable water contamination & subsidence** problems

If the product gas is directly used in gas turbines, **additional compression may not be necessary**



UCG Site Selection Factor
Coal Seam Thickness



Thicker seams need fewer wells, so reducing drilling costs

Often **problems** when attempting **to gasify seams < 2m thick**

Heat losses are considerable with thin seams, leads to low thermal efficiency & lower product gas quality

UCG is **generally easier to sustain in dipping seams** as tars & fluids flow away from the gasification zone

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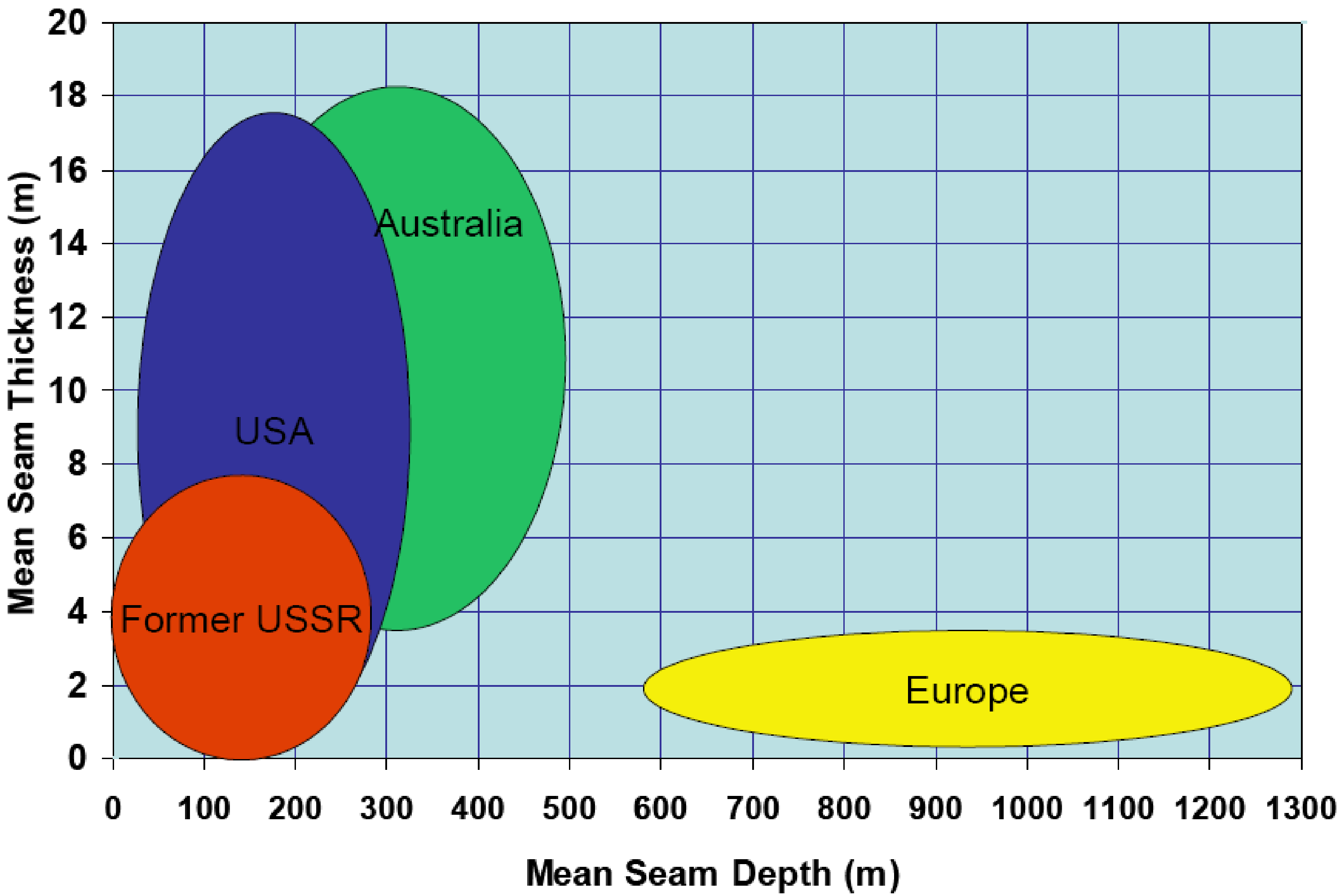
Worldwide UCG Experience
Coal Seam Depth & Thickness



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Process parameter: Operating Pressure ~ governed by coal & rock properties

1. Higher pressure in UCG working zone **assures no groundwater flow seeping into the cavity**
2. Influences **chemistry & contamination**
3. Pressure **increases with depth** of seam
4. Higher values will increase the **loss of the product gas**
5. An **impermeable overburden** helps provide a reasonable balance between pressure & gas losses
6. Deep seams with high coal & overburden permeability pose a problem (pressure can **make gas losses unacceptable)**

"Best Practices in Underground Coal Gasification", E.Burton, J.Friedman, R. Upadhye, Lawrence Livermore Nat. Lab., DOE Contract No. W-7405-Eng-48

Process parameter: Outlet Temperature ~ governed by coal & rock properties

Ideal UCG temperatures are similar to above ground coal gasification temperatures, **> 1000°C (1832°F)**

Achieving the ideal UCG temperatures depends on **careful control of the water influx & gas flows**

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Site Selection Factors Porosity & Permeability

More **permeable seams make it easier** to link the injection & production wells, & increases the rate of gasification by making reactant transport easier

But higher porosity & permeability **increase the influx of water, & increase product gas losses**

Seam permeability can be artificially enhanced through various methods

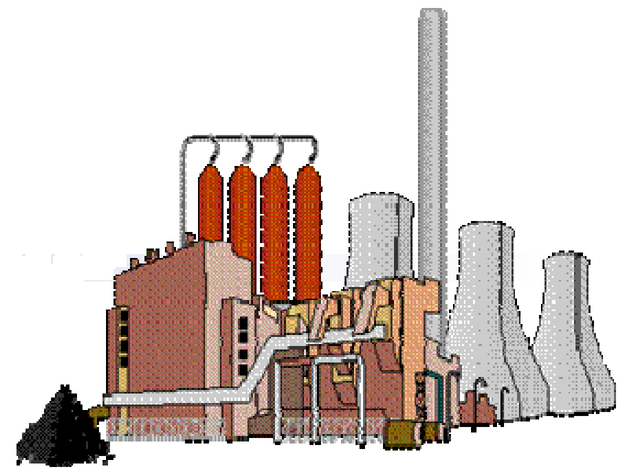
CO_2 Emissions from Coal

Different rank coals produce different amounts of CO_2 lbs per Million Btu (MBtu)

<u>CO_2 pounds/MBtu from Coal</u>

U.S. averages:

- **227.4** for **anthracite**
- **216.3** for **lignite**
- **211.9** for **sub-bituminous**
- **205.3** for **Indiana bituminous**



Consider pumping CO_2 back into the UCG cavity for permanent storage

Souce: http://www.eia.doe.gov/cneaf/coal/quarterly/co2_article/co2.html

Attractions of UCG

Less than one sixth of the world's coal is economically accessible & so **UCG increases usable coal resources**

Potential UCG sites correspond to locations where sites are plentiful for **CO_2 sequestration**

The syngas produced is taken from the ground & **then by-products are taken out (CO_2 being returned)**

Attractions of UCG

Reduced expenditure, no gasifier is required to be purchased, reduced transportation & no ash removal operational costs

UCG provides a **clean & economic alternative** fuel

Further information: https://eed.llnl.gov/co2/11.php

CARBON MANAGEMENT PROGRAM Lawrence Livermore National Laboratory