

# Effects of Rock Deformation and Groundwater Influx in Controlling Efficiency and Extraction rate in Underground Coal Gasification

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# Questions:

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Does UCG work?

Is there a UCG technology that can be commercially used in Europe?

# What Makes a UCG Technology Commercial?

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## Environmentally Clean Operation with:

- Consistent Quality (e.g. Wobbe index variation  $\leq 5\%$ )
- Consistent Quantity (energy output variation  $\leq 1\%$ )
- Commercial Scale - over a million tonne a year for  $\geq 30$  years



# Commercial Scale Plant

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- Large Geological Coal Resource  $\geq$  50 MT
- High Extraction Efficiency
- Size for Greenfield Applications is determined by Syngas Consumer Plant:

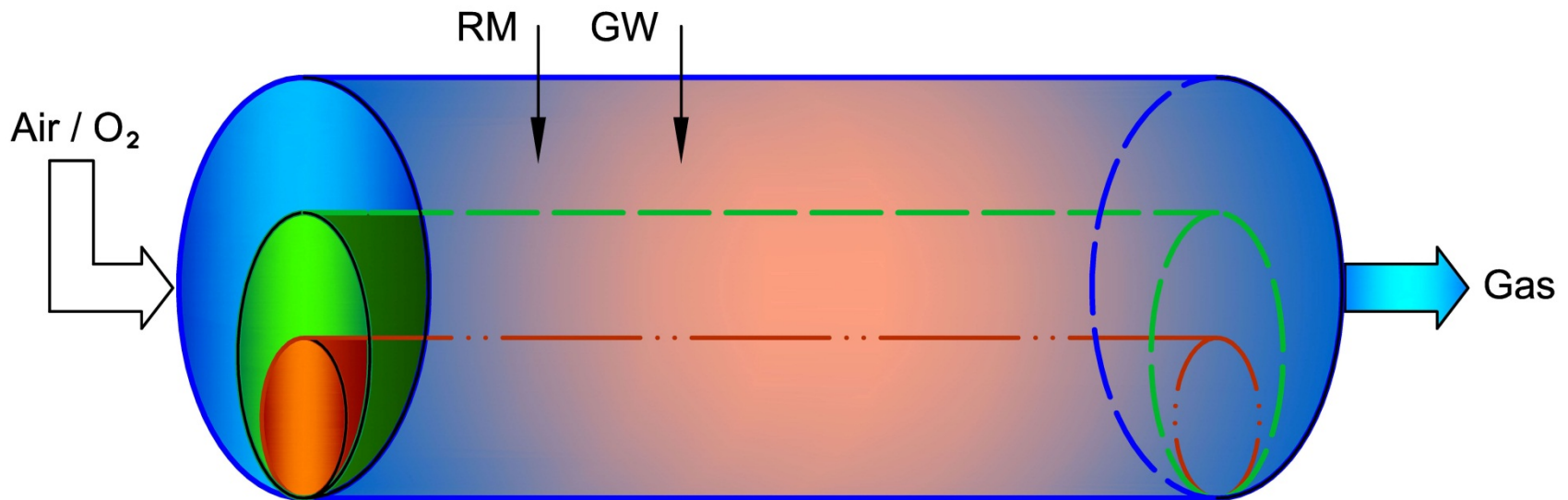
World-Scale Plant Capacity	UCG Coal Consumption
10,000 bblpd of Synthetic Gasoline	3 MT per annum
300 MW <sub>e</sub> IGCC Power Plant	1,7 MT per annum
3,500 tpd of Urea	2 MT per annum
25 BCF of SNG	3 MT per annum
10,000 bblpd of Diesel	4 MT per annum

# Consistent Quality?

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Inherent inconsistency of gas quality in linear UCG reactors:

Growing diameter  $\Rightarrow$  lower gas velocity  $\Rightarrow$  less turbulence  $\Rightarrow$  worse mass exchange  $\Rightarrow$  dropping gas quality

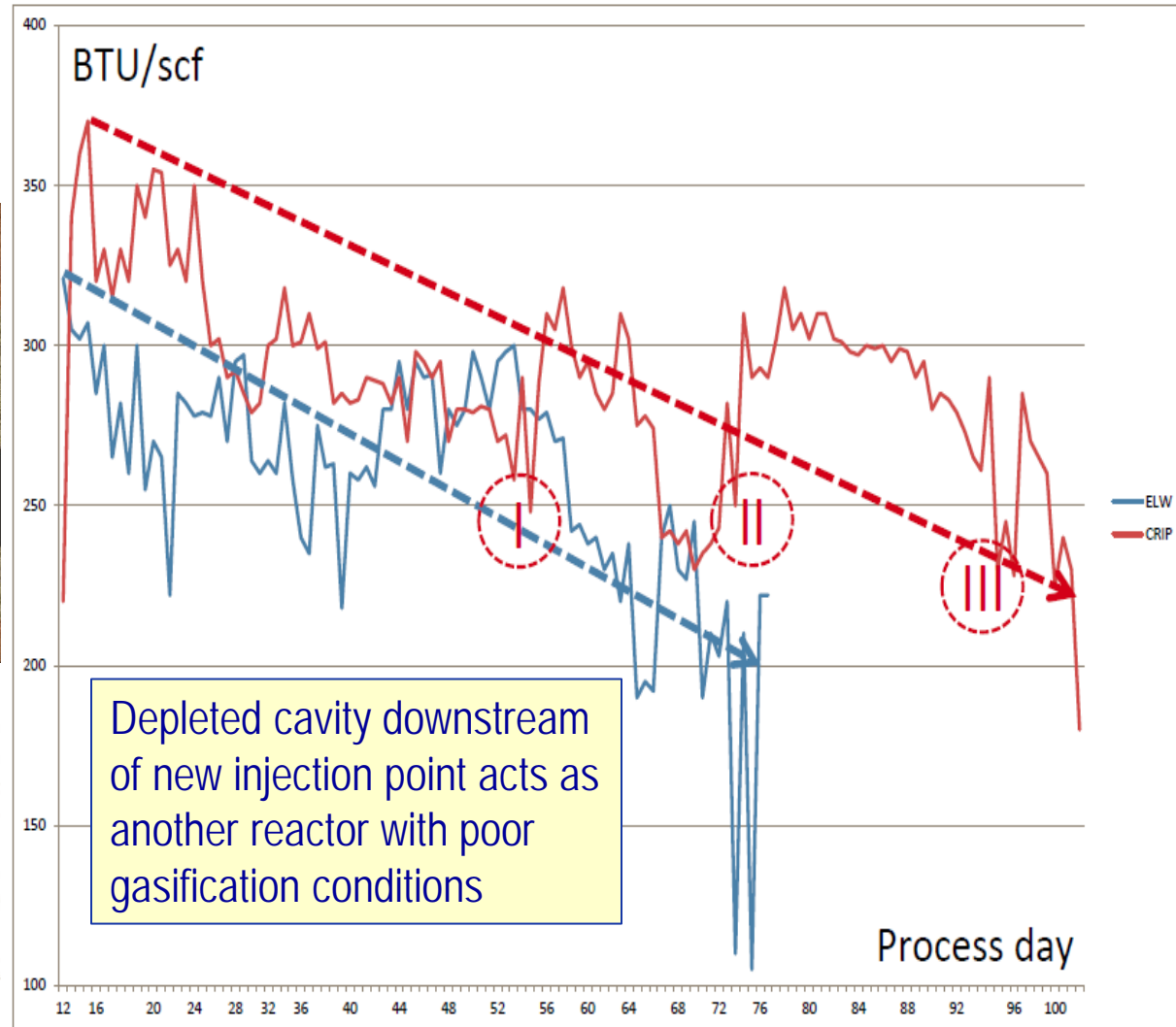
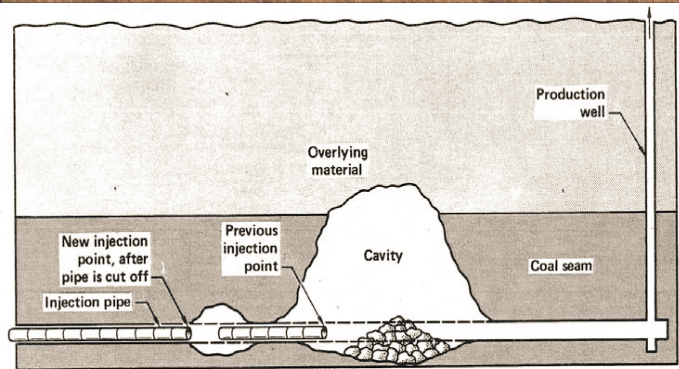
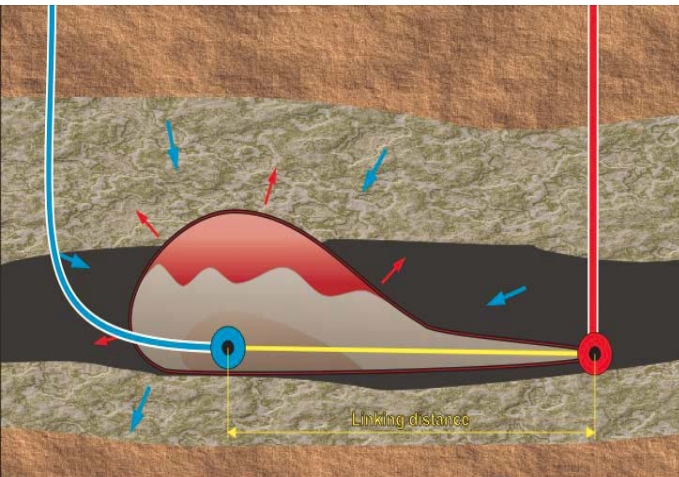


# Consistent Quality?

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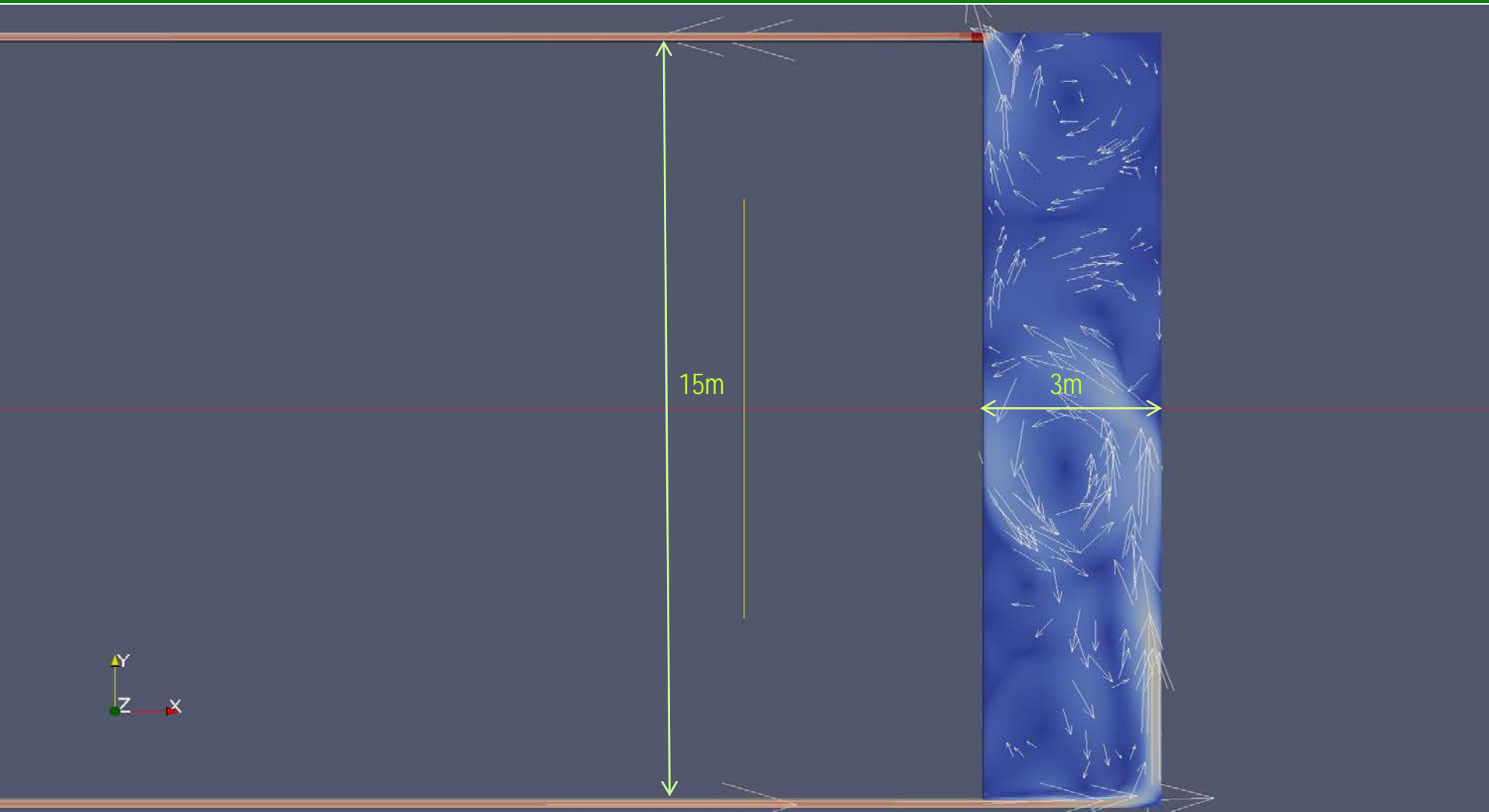
## RM1 CRIP:

Gas quality consistently drops despite CRIP maneuvers

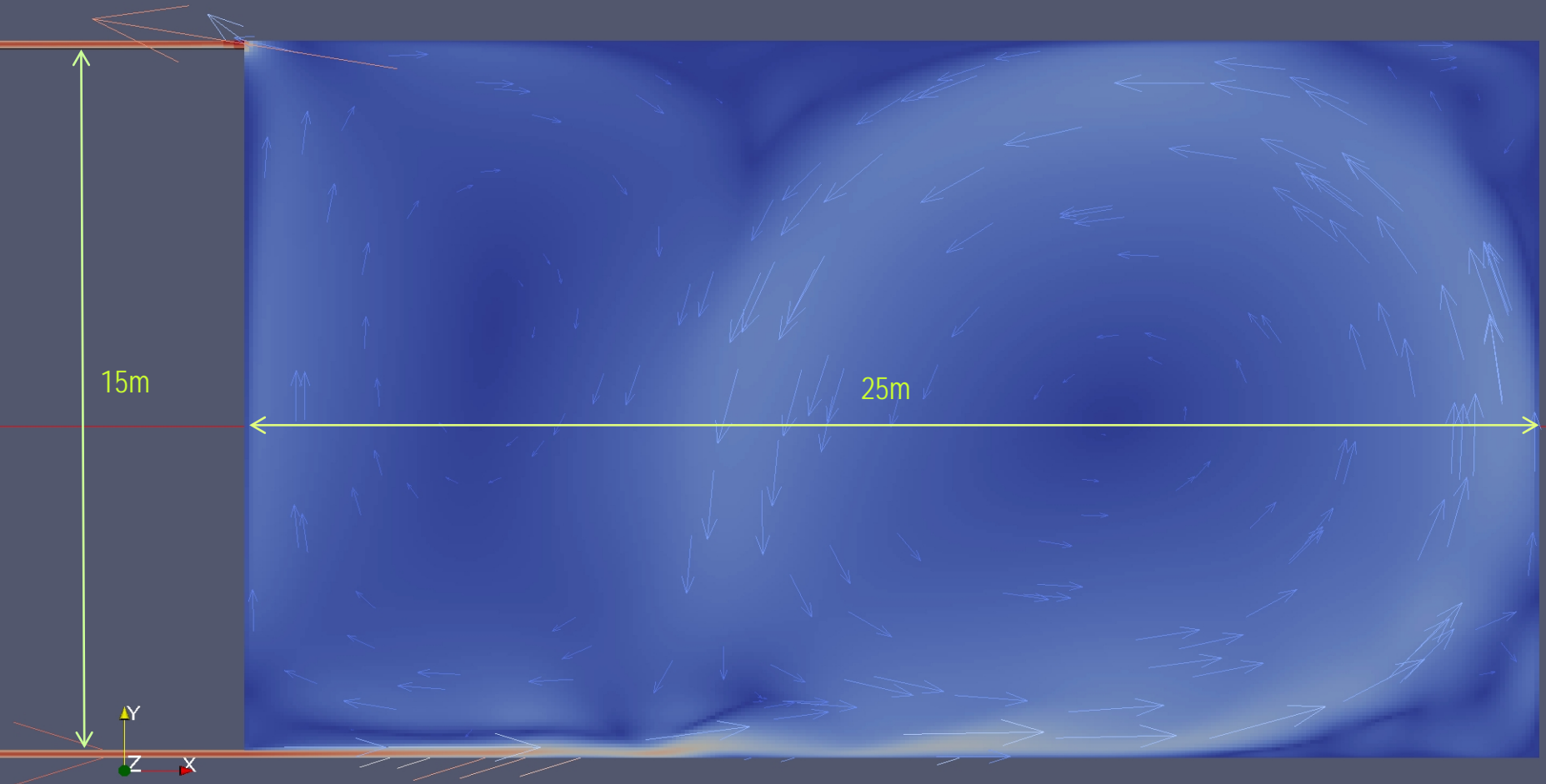


# Mass and Energy Exchange – 3m channel

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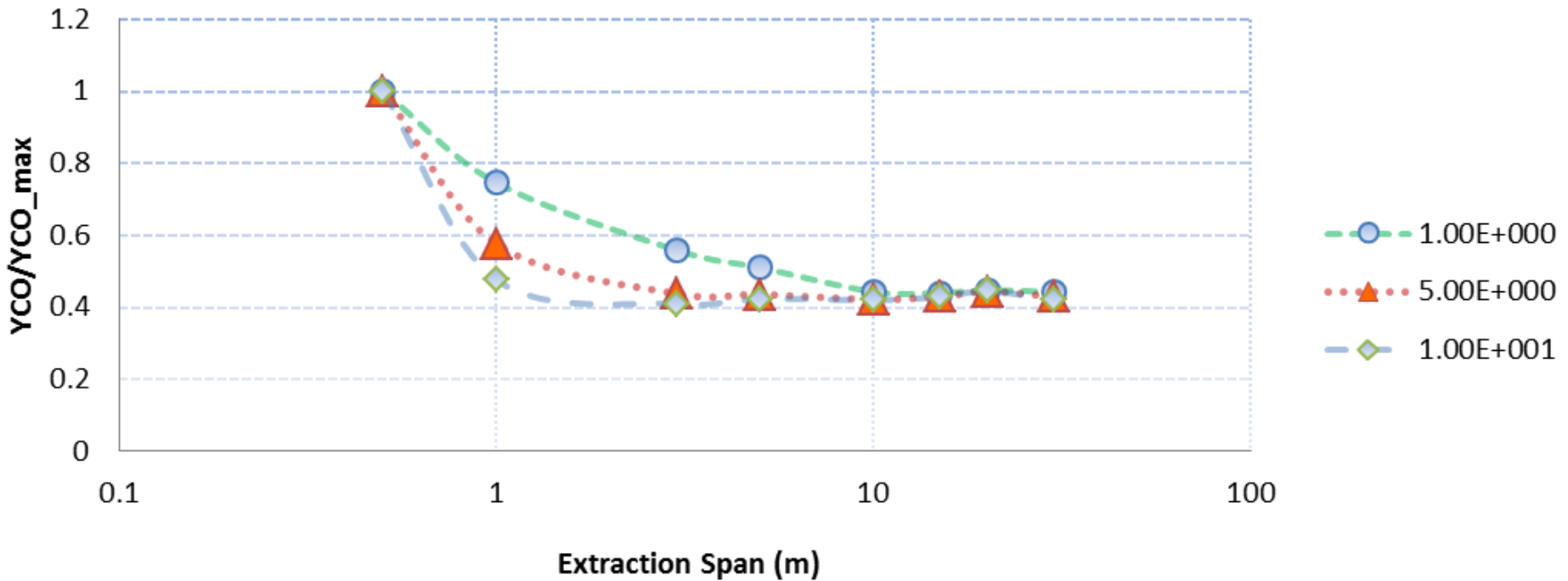
# Mass and Energy Exchange – 25m channel



# Yield of CO in Growing Cavity

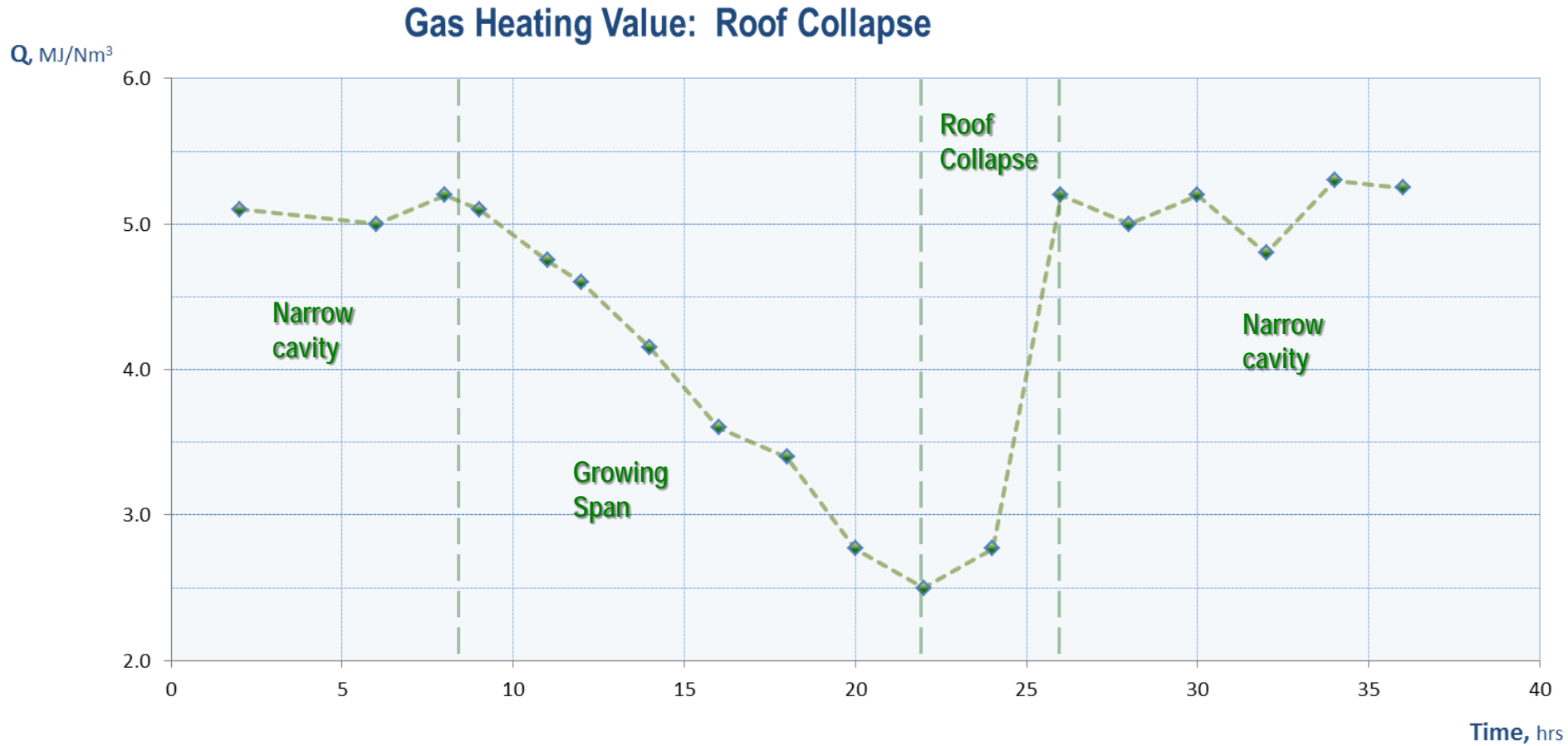
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## YCO/YCOmax vs. Extraction Span



# Gas Quality during Roof Collapse

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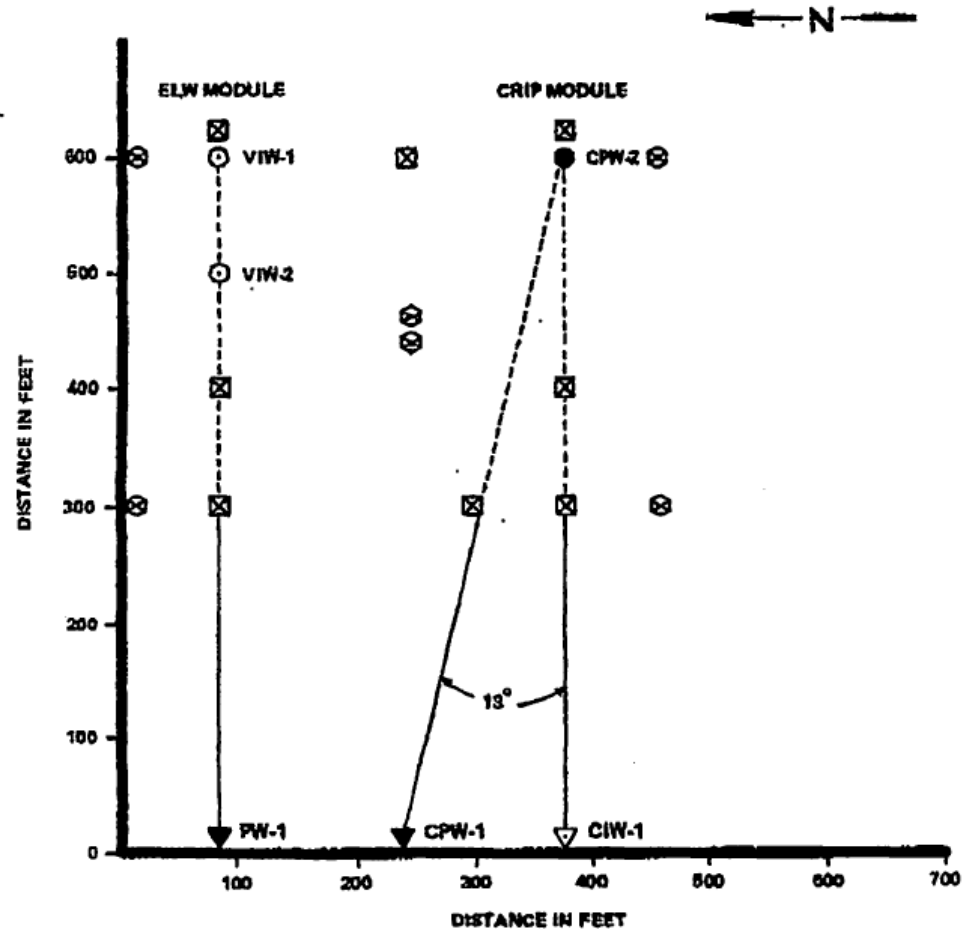


# CRIP: Mine Plan

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## Rocky Mountain 1 field trial, Wyoming, USA, 1986-1988:

- Spacing between CRIP and ELW modules – over 300ft (~100m);
- Duration – 100 days;
- Coal Extraction – 10,000 t
- Cross-flow of the injection agent and product gas between the two modules during operations and post-shutdown activities;
- The magnitude of cross-flow at least 2-3%.



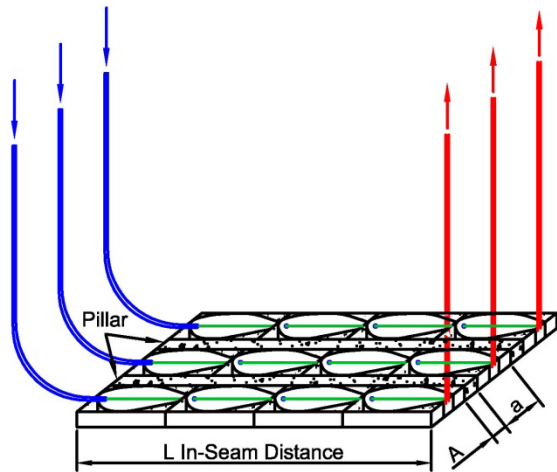
# CRIP: Mine Plan

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(a)

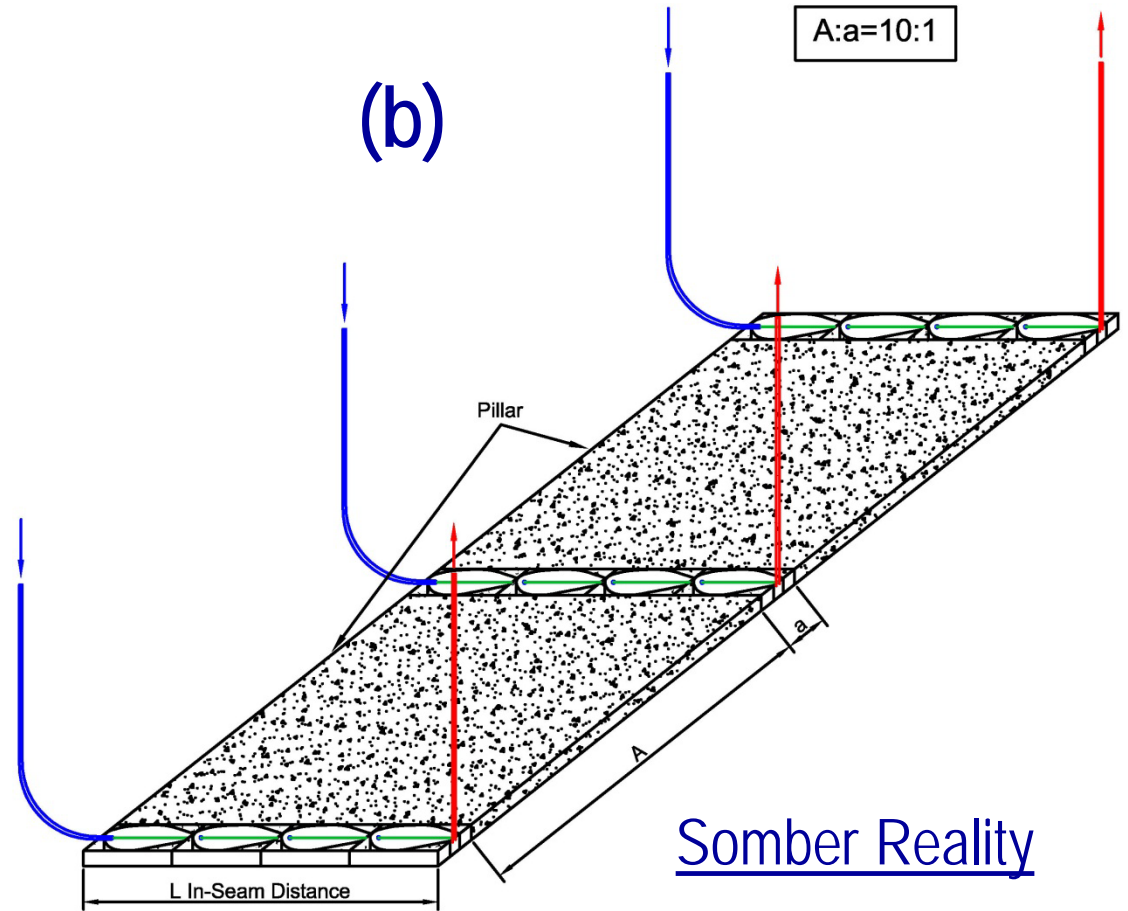
Proponents' Dream

$A:a=1:3$



(b)

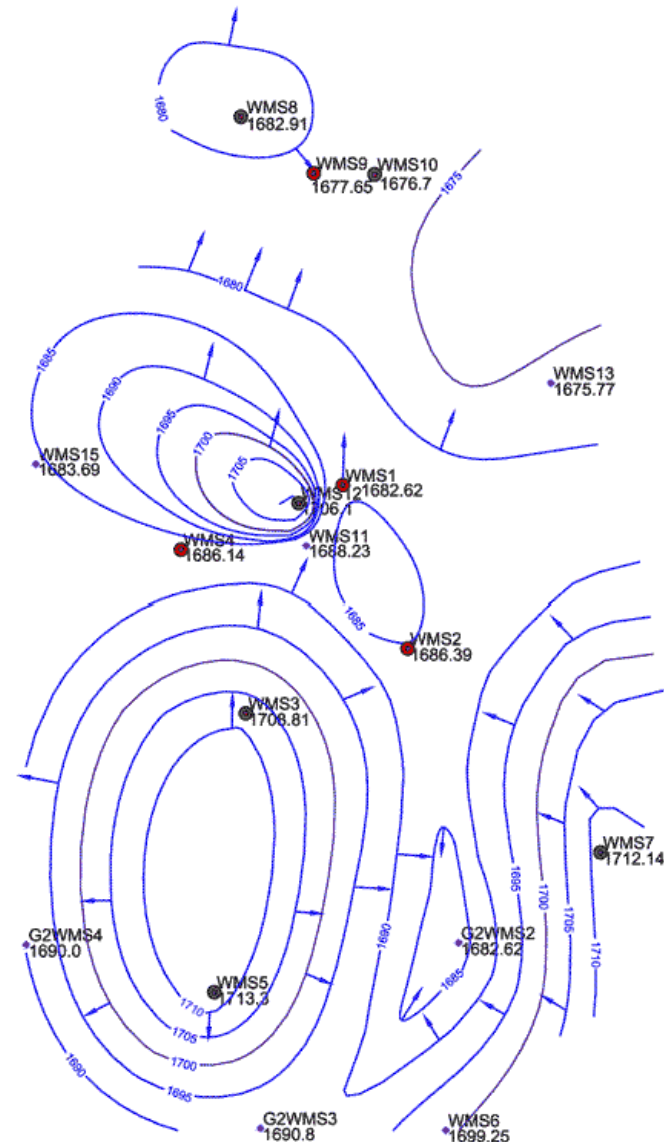
$A:a=10:1$



# Groundwater and commercial UCG Process

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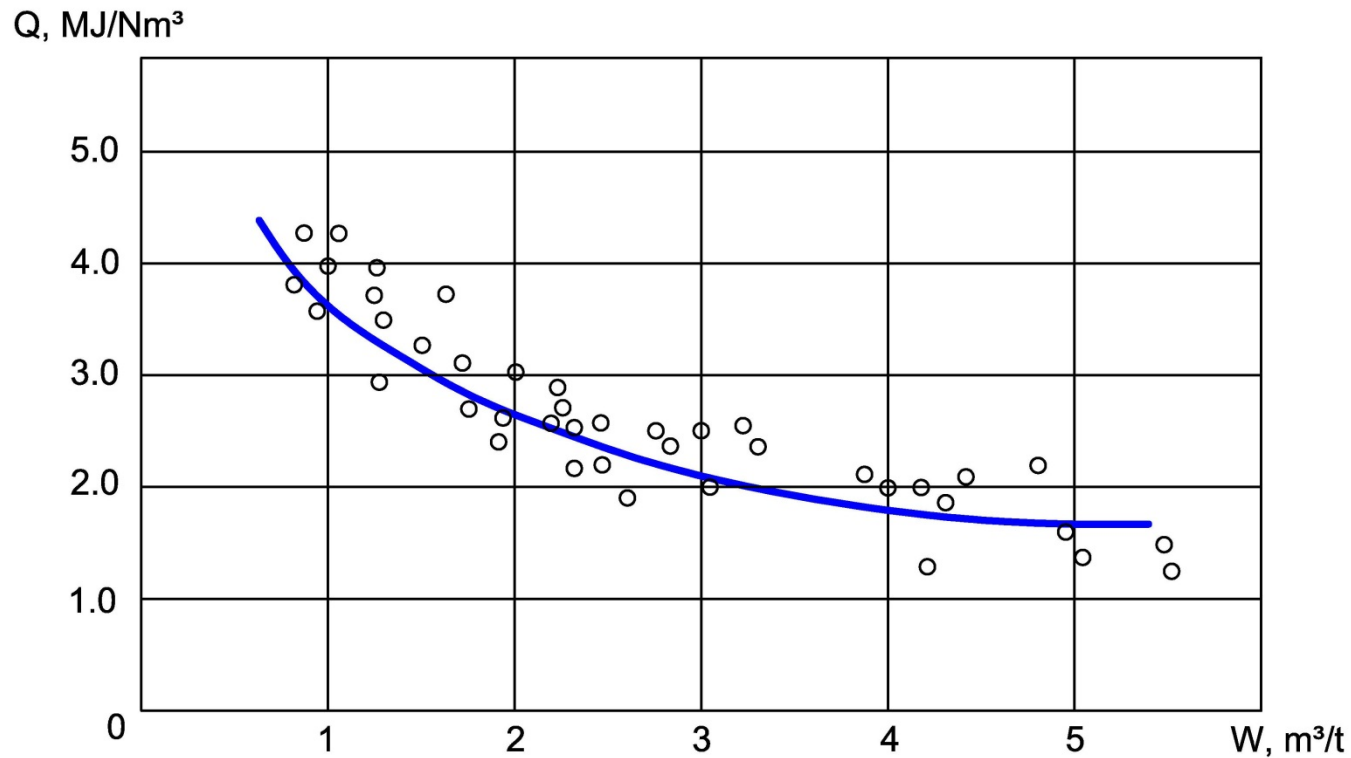
- Hydrostatic pressure of groundwater – critically important process parameter: must be monitored by the minute
- Hydrostatic pressure is constantly changing as function of
  - aquifer depletion due to groundwater consumption in the cavity
  - Variations in aquifer recharge
- Rock deformation above developing cavity affects groundwater pressure by inducing permeability and creating groundwater sinks
- Hydrostatic pressure and gas pressure in the cavity are in an interdependent intricate relationship – their interaction must be carefully controlled using predictive models
- Cavity pressure must be constantly adjusted to maintain exact pressure gradient towards the cavity



# Groundwater and commercial UCG Process

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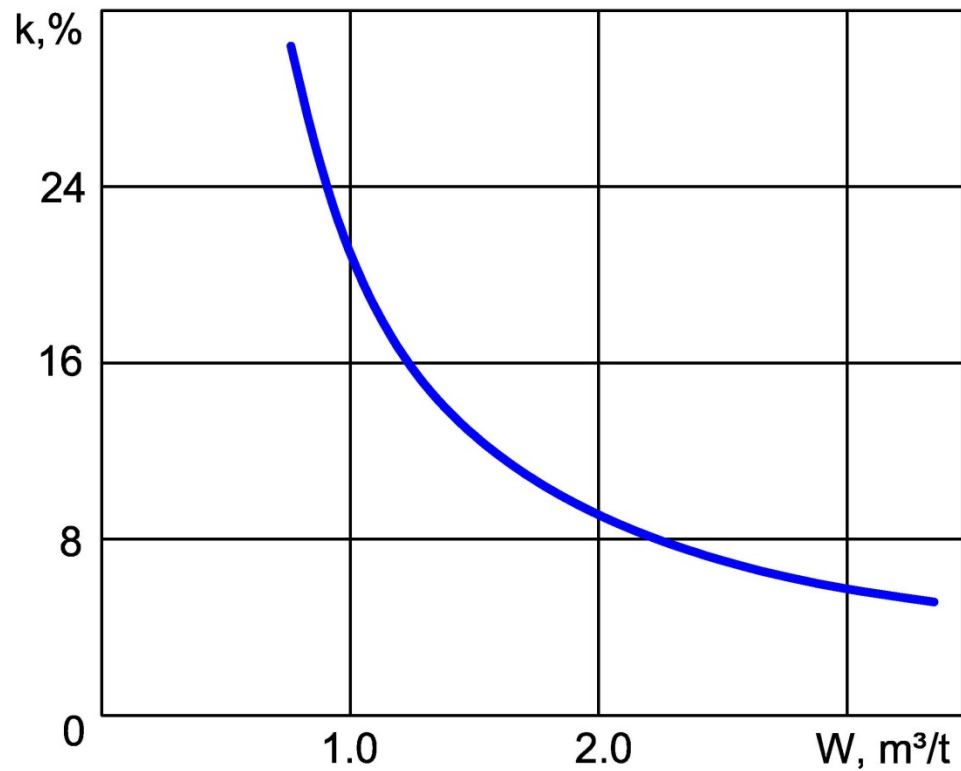
## Gas LHV as Function of Groundwater Influx per ton of Coal Consumed



# Groundwater and commercial UCG Process

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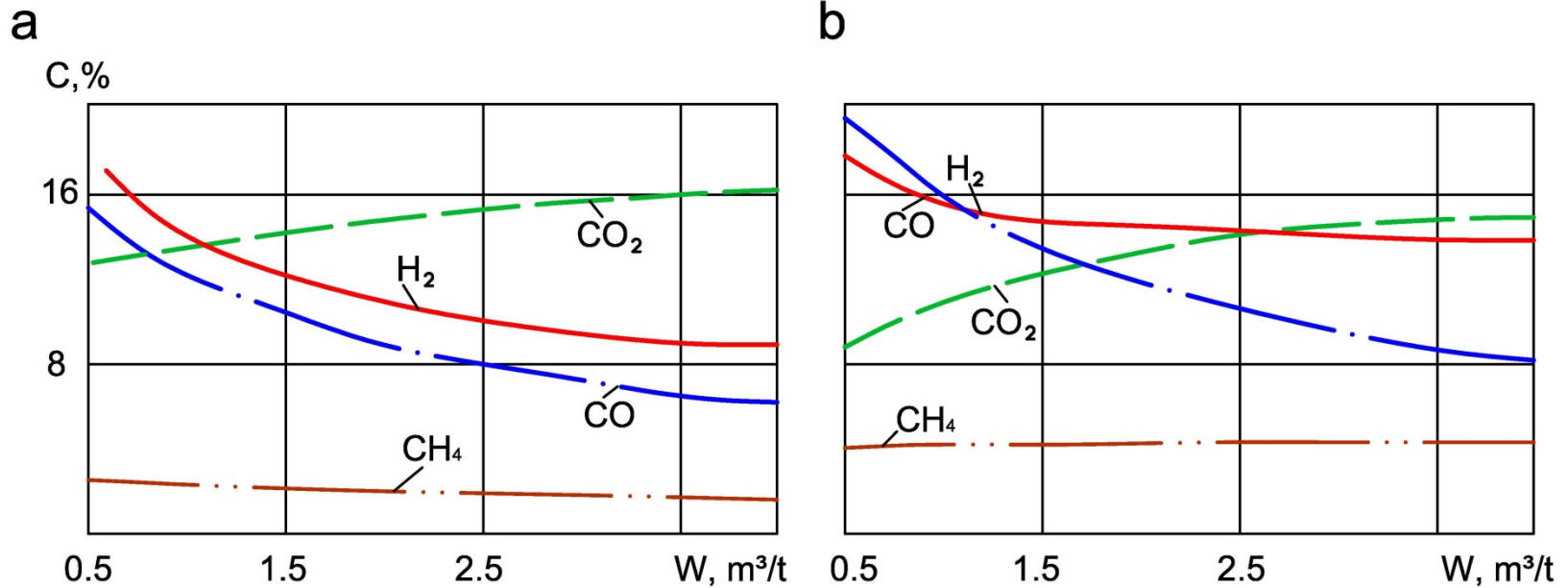
Steam Conversion Rate as Function of Groundwater Influx per ton of Coal Consumed



# Groundwater and commercial UCG Process

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Gas Constituents as Function of Groundwater Influx per ton of Coal Consumed



a) Bituminous coal seam, thickness 4.2m

b) Subbituminous coal seam, thickness 10.4m

# εUCG Technology

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- Large-scale coal mining technology (over 0.3 MT/a)
- Incorporates rock deformation and ground water influx
- Injects oxygen, air, H<sub>2</sub>O, CO<sub>2</sub> etc.
- Drilling of directional, inclined, vertical and other wells
- Modern technology based on 70+ years of Soviet work
- Optimized for great depth coal/lignite deposits
- Applied in international commercial projects: the USA, Canada, New Zealand, South Africa, Australia, China, India etc.

# εUCG Technology

## All Kinds of Coal

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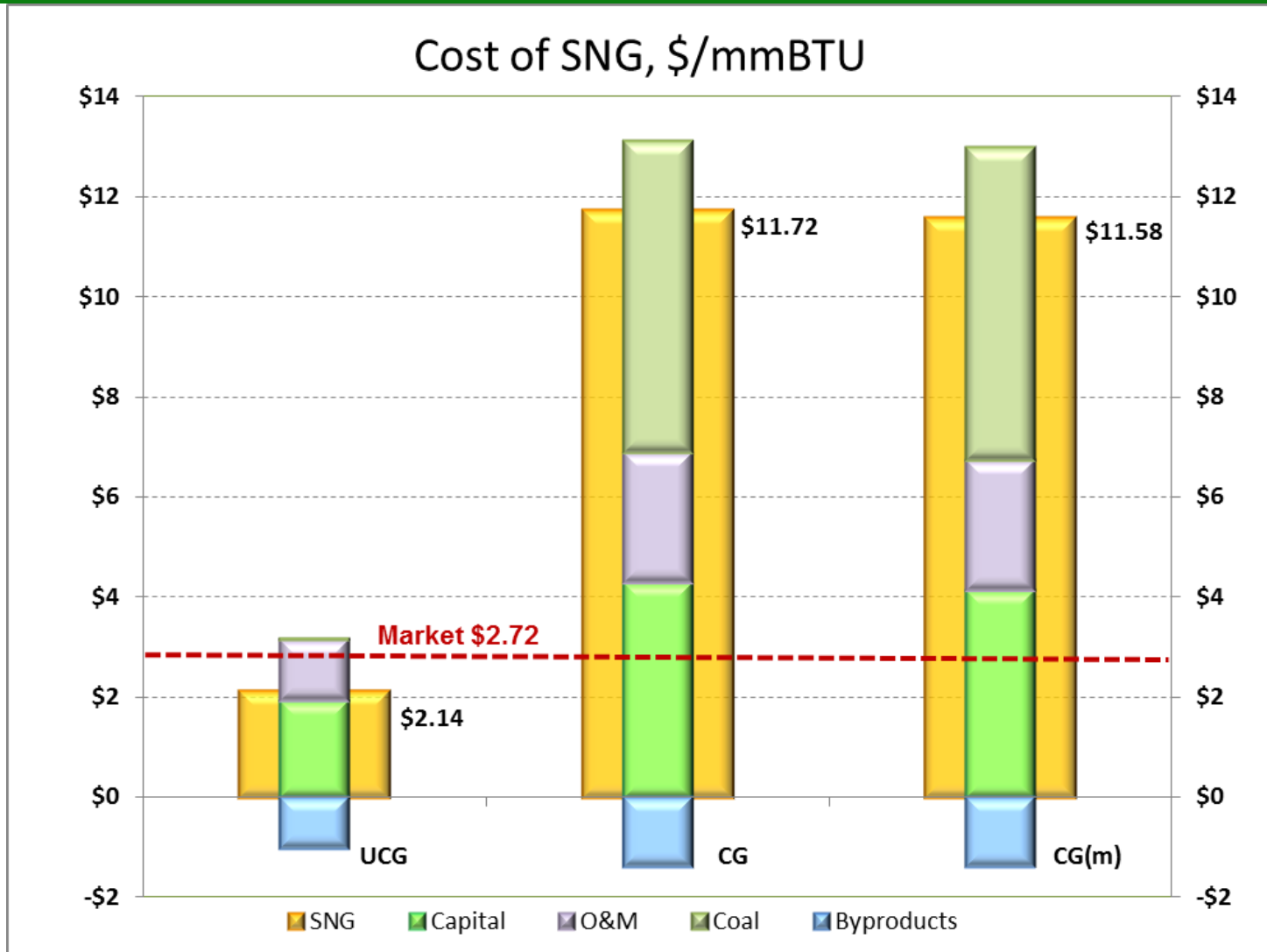
UCG Plant	Rank	Thickness, m	Depth, m	Dip°	LHV, MJ/kg
<i>Lisichansk</i>	Bituminous	0.44 - 2.0	60 - 250	38 - 60	20.1 - 23.0
<i>Yuzhno-Abinsk</i>	Bituminous	2.2 - 9.0	130 - 380	35 - 58	28.9 - 30.7
<i>Podmoskovnaya</i>	Lignite	2.5	30 - 80	<1	11.8
<i>Angren</i>	Lignite	3.0 - 24.0	110 - 250	7	15.3
<i>Shatskaya</i>	Lignite	2.6	30 - 60	<1	11.0
<i>Sinelnikovo</i>	Lignite	3.5 - 6.0	80	<1	8.0
<i>Chinchilla</i>	Sub-bituminous	10.0	135	<1	21.7
<i>Majuba</i>	Bituminous	3.5-4.5	285	3	20.3
<i>Kingaroy</i>	Sub-bituminous	17.0	200	5	23.5
<i>Huntly West</i>	Bituminous	4.0-22.0	220-540	0-75	24.5
<i>CC Alberta</i>	Sub-bituminous	7.0	150-260	6	20.5-23.0
<i>Alaska SHR</i>	Lignite/ Sub-bituminous	1.0-12.0	50-1,650	0-75	11.0-16.5



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# εUCG vs. CG – SNG (India 2014)

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# Is there a UCG technology that can be commercially used in Europe?

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## The Exergy UCG™ (εUCG) –

the Source of Hydrocarbons from Unminable Coal:

- Indigenous and safe
- Environmentally Clean and Carbon Efficient
- Cost Competitive
- for Power Generation
- for Synthesis of Clean Fuels & Chemicals

# Thank you!

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