# *The Potential for Underground Coal Gasification*

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# Content

- Introduction
- European hard coal mining industry
- Underground coal gasification for Europe and Kazakhstan
- Polish activities in underground coal gasification
- Conclusions

# Coal - Global Energy Source

- Coal is abundant and relatively cheap today (coal occurs in over 70 countries around the world)
- Coal is one of the most important fuels for generating electricity and perhaps for extensive syngas production in the future (Global coal consumption increased by about 4.5% during 2006)
- Lignite and hard coal has been an energy source for hundreds of years in Europe
- ……
- Coal faces significant environmental challenges in mining: waste, surface subsidence, air pollution and emission of $CO_2$, , ...

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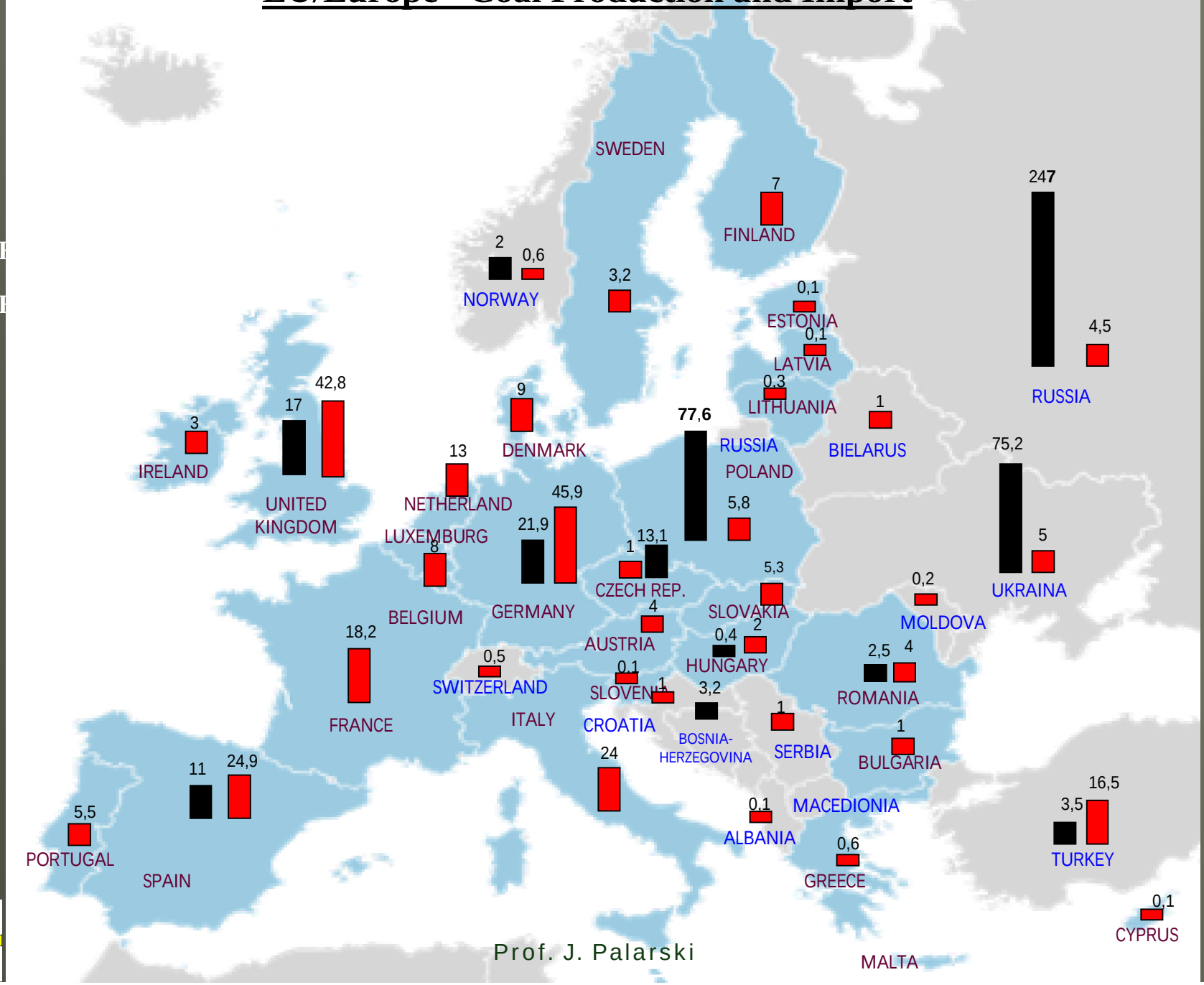
# EU/Europe - Coal Production and Import

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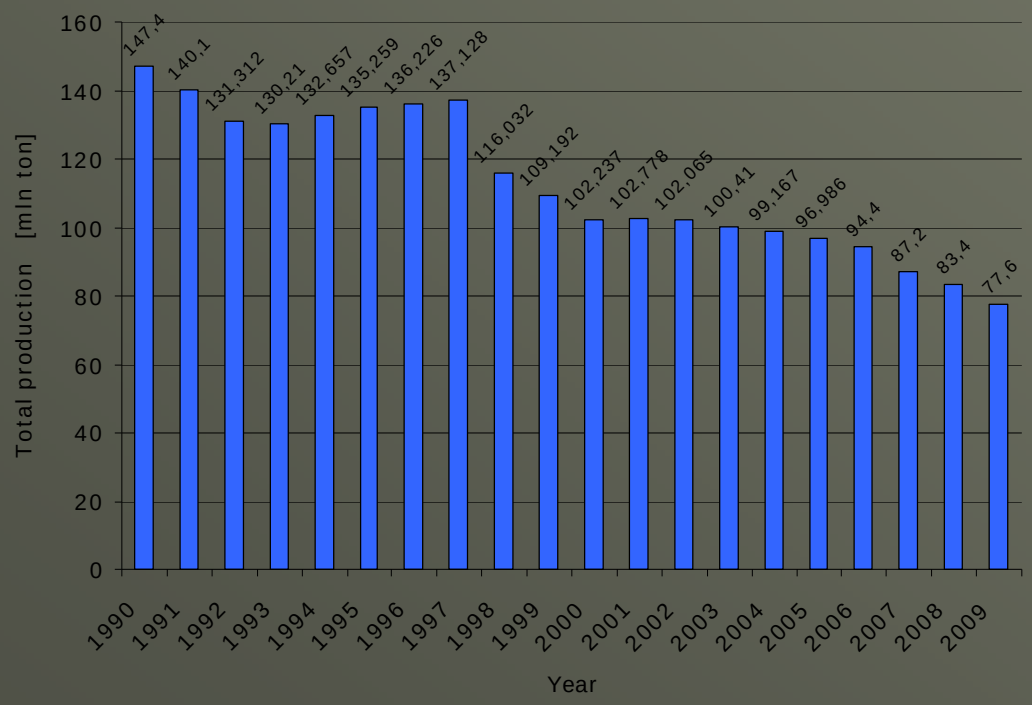
# Polish Hard Coal Production




## Coal in Poland

**Over 77 Mt of hard coal and almost 60 Mt of lignite is currently produced (2009)**

**Coal plays a vital role in power generation – 93%**

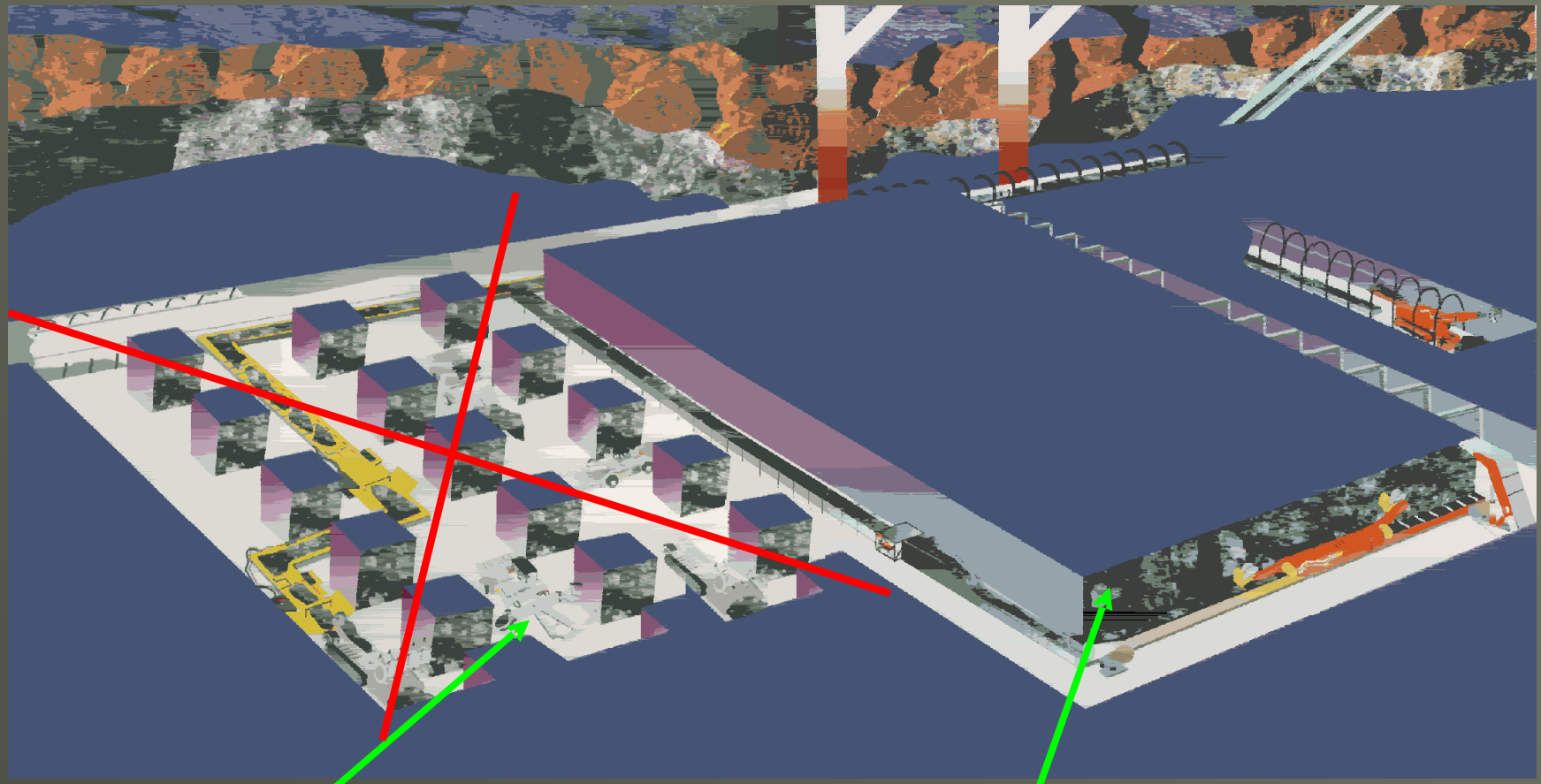
**Almost 95% of Polish steel production is dependent on coal**

**Coal will continue to play a key role in the Polish energy mix**

**…**

**Coal faces significant environmental challenges in mining: waste, surface subsidence, air pollution and emission of CO2, …**

# MINING METHODS



Investment: $5-10M

Longwall panels are solid coal blocks, accessed by tunnels
Investment: >$70M for face equipment only

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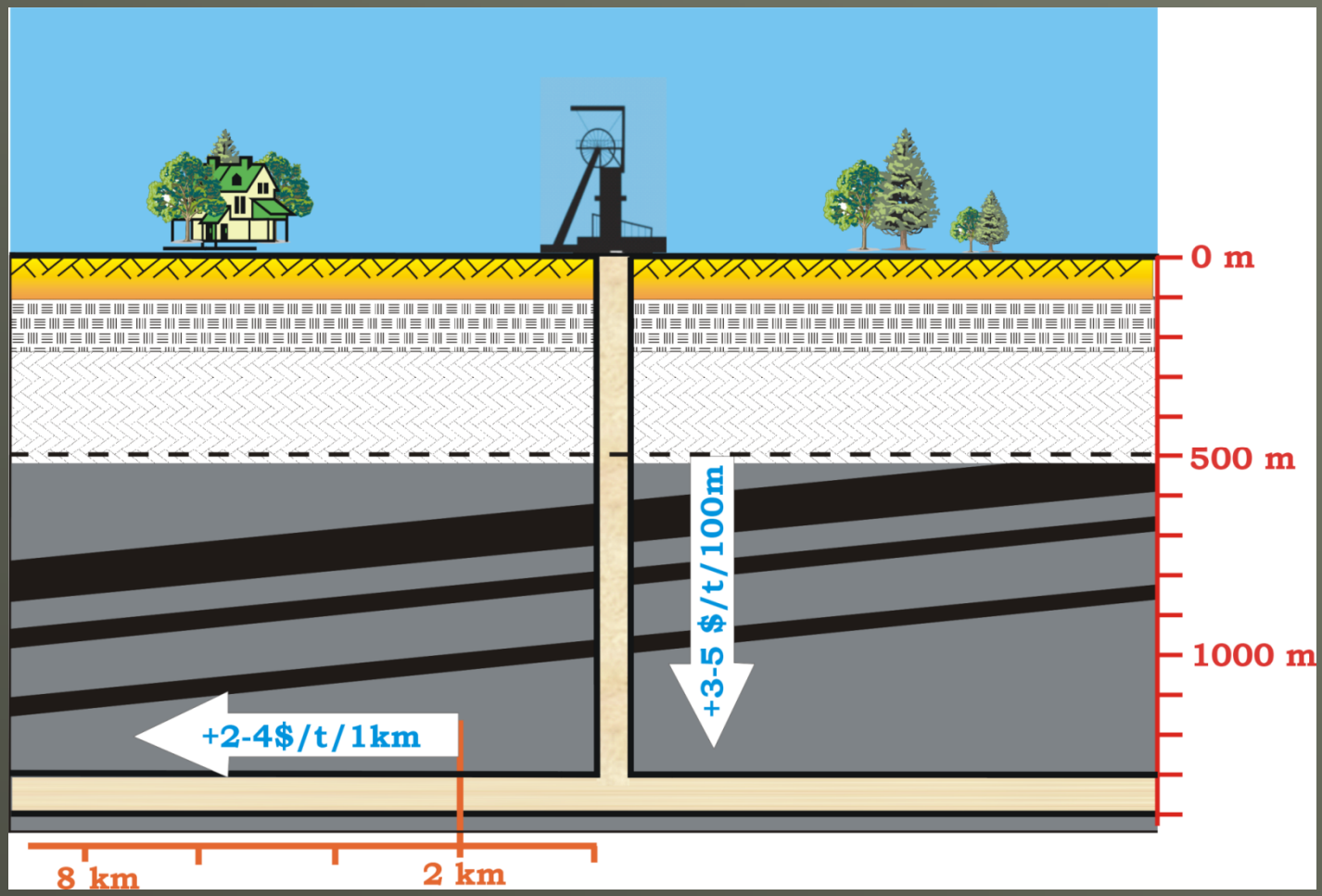
# Coal Content and Products

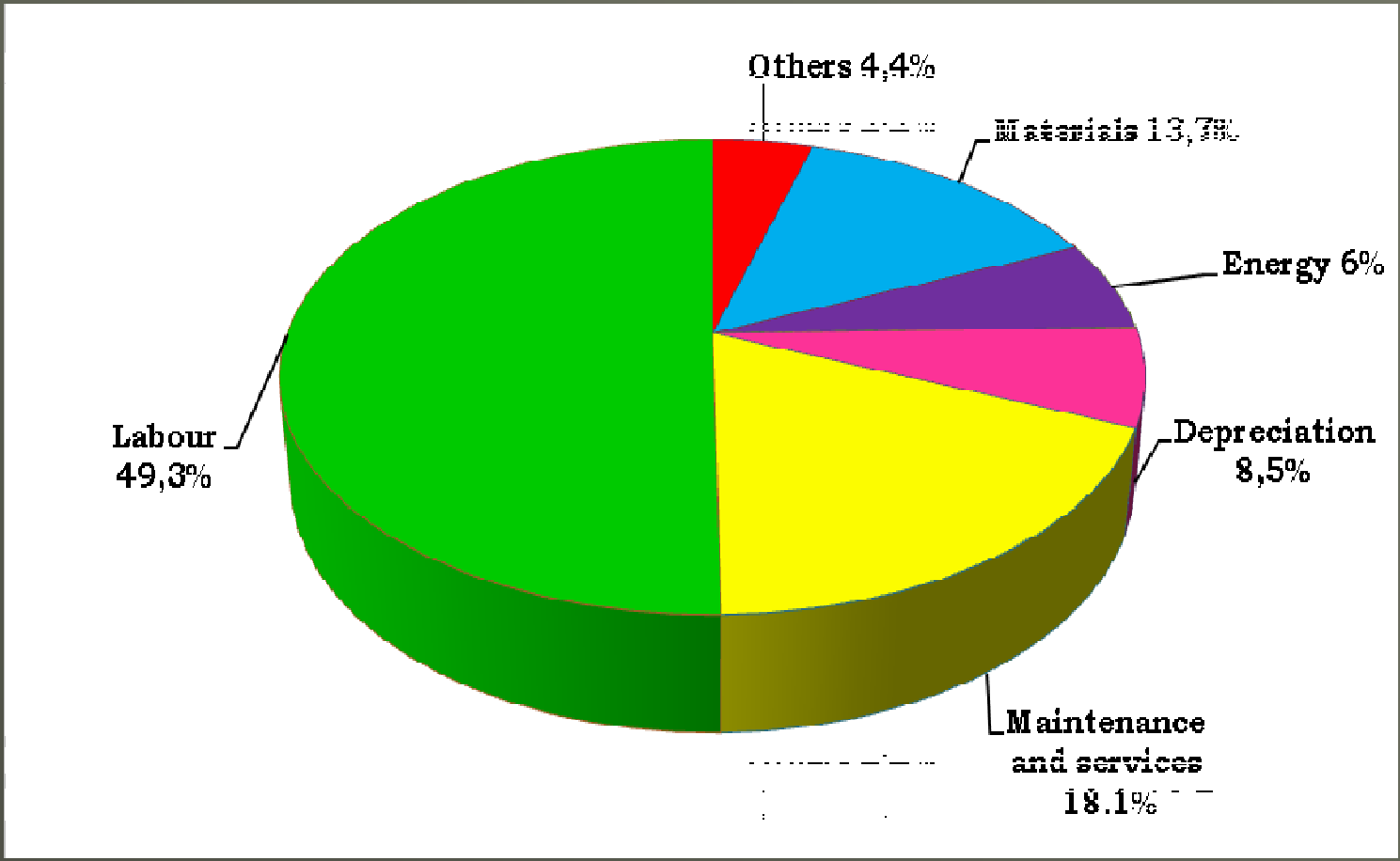
| | Lignite | Sub-Bituminous | Bituminous | Anthracite |
|---|---|---|---|---|
| Heat Content MJ/kg | 10 - 20 | 20 - 21 | 24 - 35 | 30 -35 |
| Fixed Carbon % | 25 - 35 | 35 - 50 | 50 -85 | 85 - 98 |
| Ash % | 10 - 55 | <12 | 5 - 15 | 10 -20 |
| Moisture % | 30 -70 | 10 - 45 | 3 - 15 | <12 |
| Sulphur % | 0.3 – 2.0 | < 2.5 | < 5 | 0.5 – 0.8 |
| Products - 1t of coal | Syngas < 500m$^3$ (< 7 MJ/ m$^3$) | | Syngas > 500 – 600 m$^3$ (<12 MJ/ m$^3$) | |

# Production Costs Increase with Depth and Distance to Shaft (2008)



# Structure of Coal Production Costs in Poland

(year 2008)

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# Environmental Issues

## Environmental Impacts of Coal Mining:

- Land Disturbance
- Surface Subsidence
- Water Pollution
- Waste Production

## A 1,000 MW coal power plant produces:

- 20,000 tons of $SO_2$,
- 20,500 tons of $NO_x$
- 8 million tons of $CO_2$ per year

**In a modern plant 1,000 MW-s 3 million m3/hour of flue gas are going through the chimney.**

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# Underground Coal Gasification

- UCG is the in-situ conversion of coal into a syngas through the same chemical reactions that occur in surface generator
- UCG is a gasification process carried on in non-mined and unmineable coal seams
- UCG is clean and environment friendly technology

**The main criterion for UCG site location:**

**Geologically isolated coal seems**

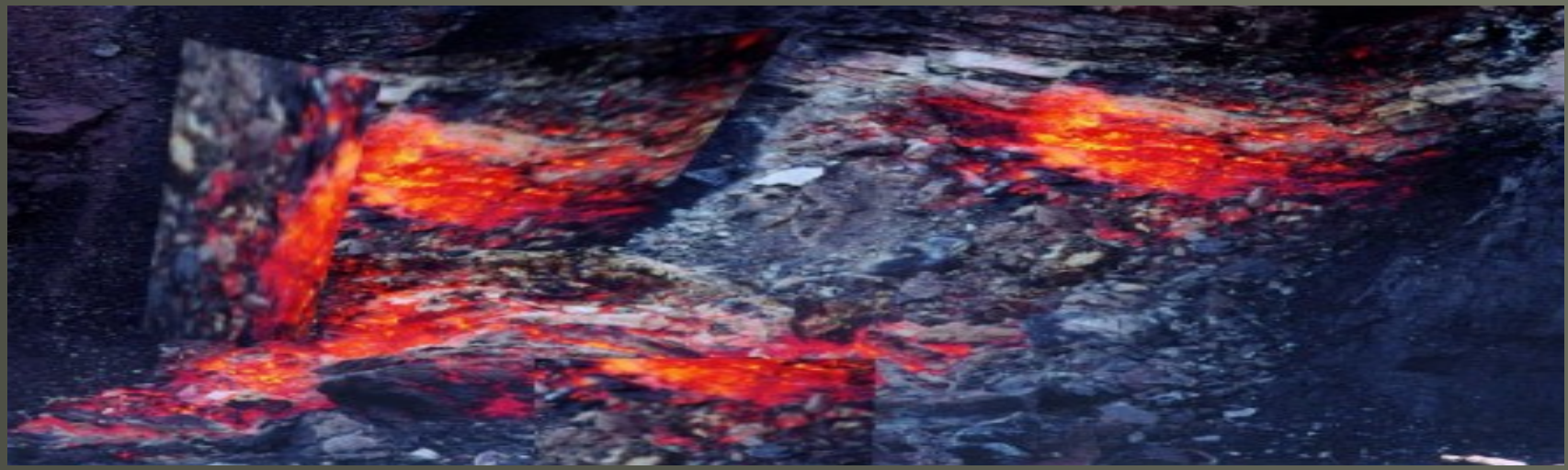
# What is Gasification?

***Gasification*** **is a controlled partial oxidation of coal to produce primarily carbon monoxide (CO) and hydrogen ($H_2$)**

***Combustion*** **is a conversion of coal into carbon dioxide ($CO_2$) and water ($H_2O$) and …**

**- Gasification:** $(C_m H_n) + ½ O_2 \bullet CO + H_2 + \ldots$

**- Combustion:** $(C_m H_n) + O_2 \bullet CO_2 + H_2O + \ldots$



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# Combustion and Gasification

## Combustion

100%C

$O_2$ +

Coal → $CO_2$

Sulphur → $SO_X$

Nitrogen → $NO_X$

Hydrogen → $H_2O$

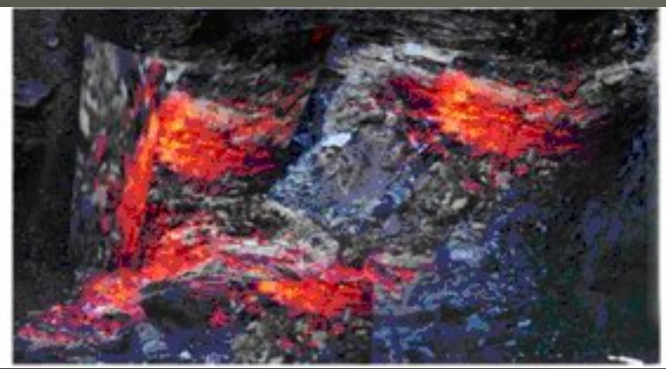
## Gasification

25-50%C

$O_2$ →

Air →

$H_2O$ steam →



→ $CO_2$

→ CO

→ $CH_4$

→ $H_2$

→ ...

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# Reactions for Underground Coal Gasification

$C_k\ H_m\ O_n \rightarrow$ coal $\rightarrow$ C

ENTALPHY

- (1) Water - gas shift reaction — • H = +118.5 kJ mol-1

  $C + H_2O = H_2 + CO$

- (2) Shift conversion — • H = - 42.3 kJ mol-1

  $CO + H_2O = H_2 + CO_2$

- (3) Methanation — • H = - 206.0 kJ mol-1

  $CO + 3H_2 = CH_4 + H_2O$

- (4) Hydrogenation — • H = - 87.5 kJ mol-1

  $C + 2H_2 = CH_4$

- (5) Semi/ Partly oxydation — • H = - 123.1 kJ mol-1

  $C + 1/2O_2 = CO$

- (6) Oxydation — • H = - 406.0 kJ mol-1

  $C + O_2 = CO_2$

- (7) Boudouard reaction — • H = +159.9 kJ mol-1

  $C + CO_2 = 2CO$

HEAT

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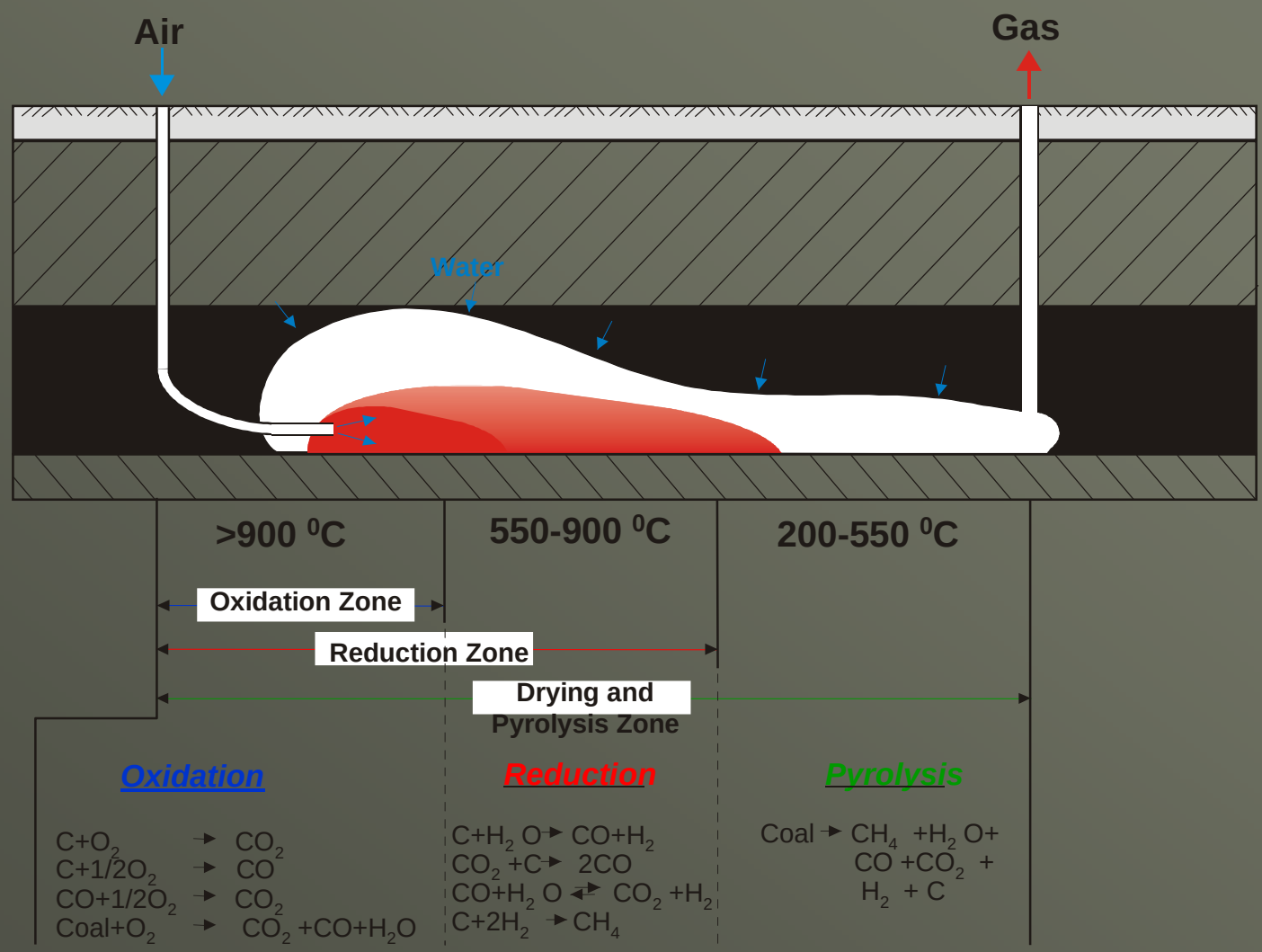
# UCG – CONTACT BETWEEN COAL & GASES

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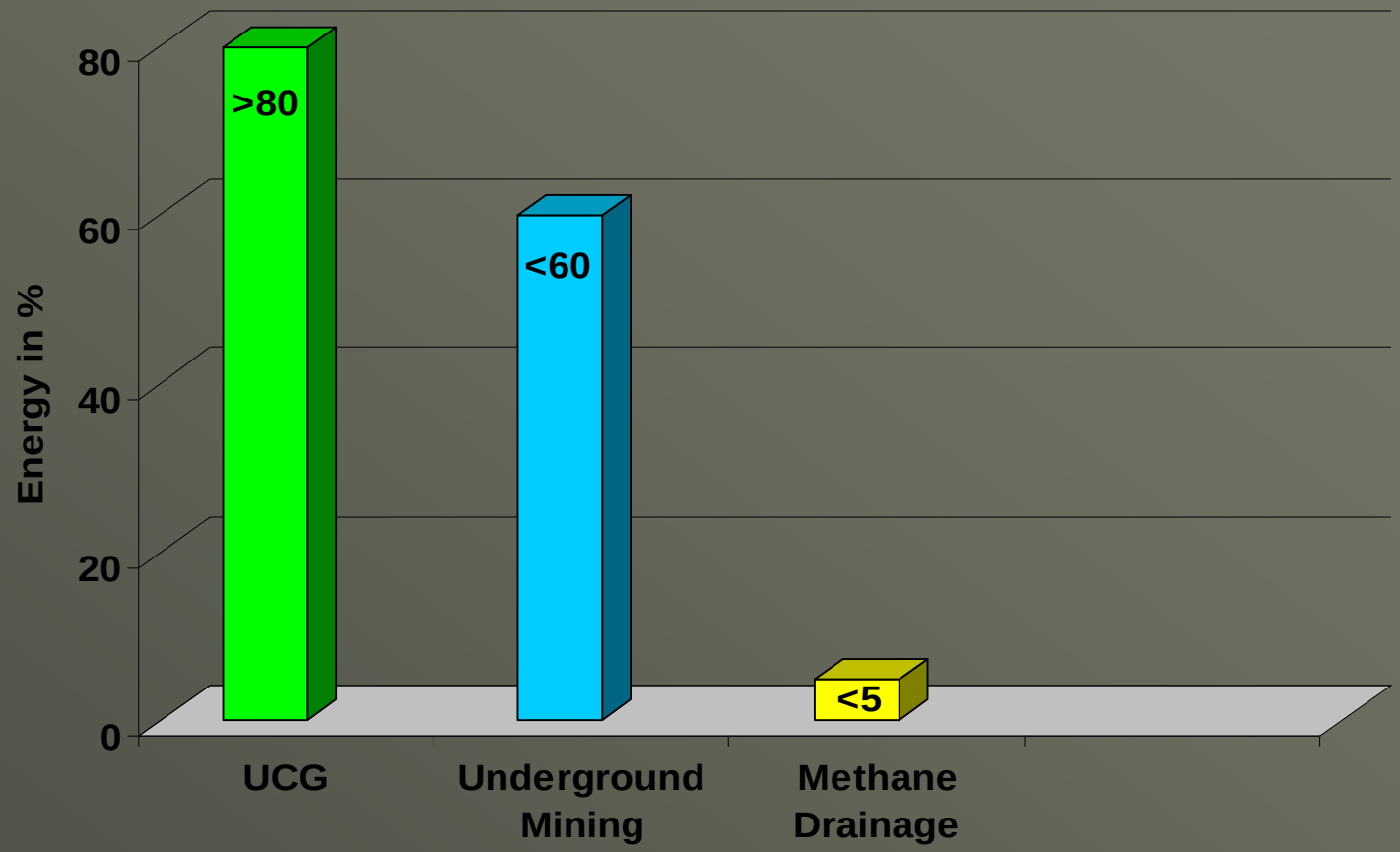
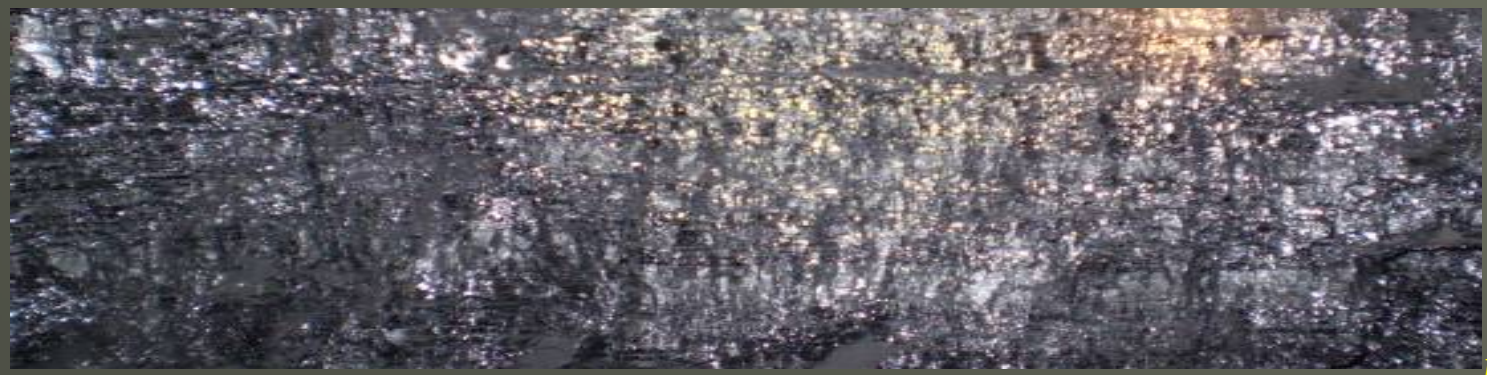
# COAL TO ENERGY CONVERTION



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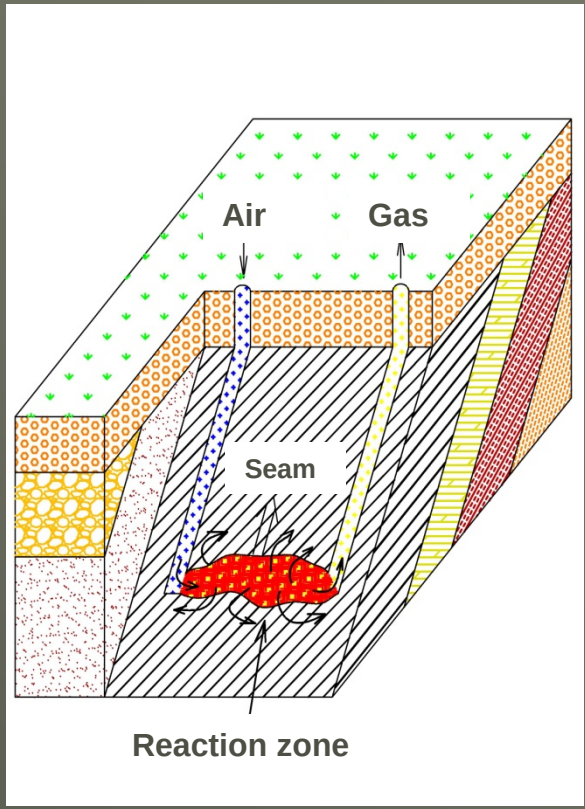
# UCG Efficiency

| | Efficiencies |
|---|---|
| Current traditional coal burning | 30% - 38% |
| Current gasification | 50% |
| Future gasification | 70-80% |

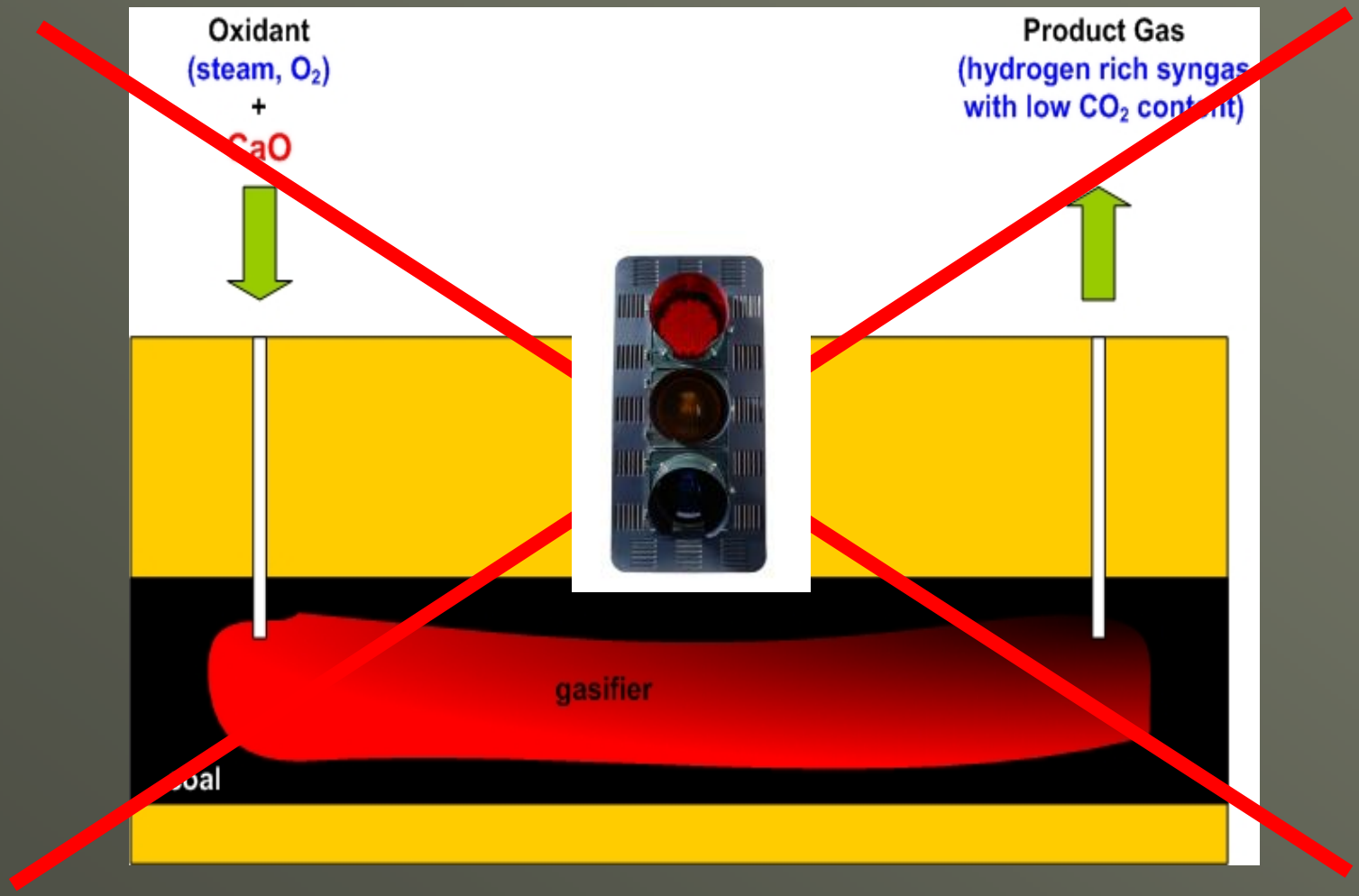
***Coal gasification*** **is much more efficient than coal burning in power plants**

# What affects UCG?

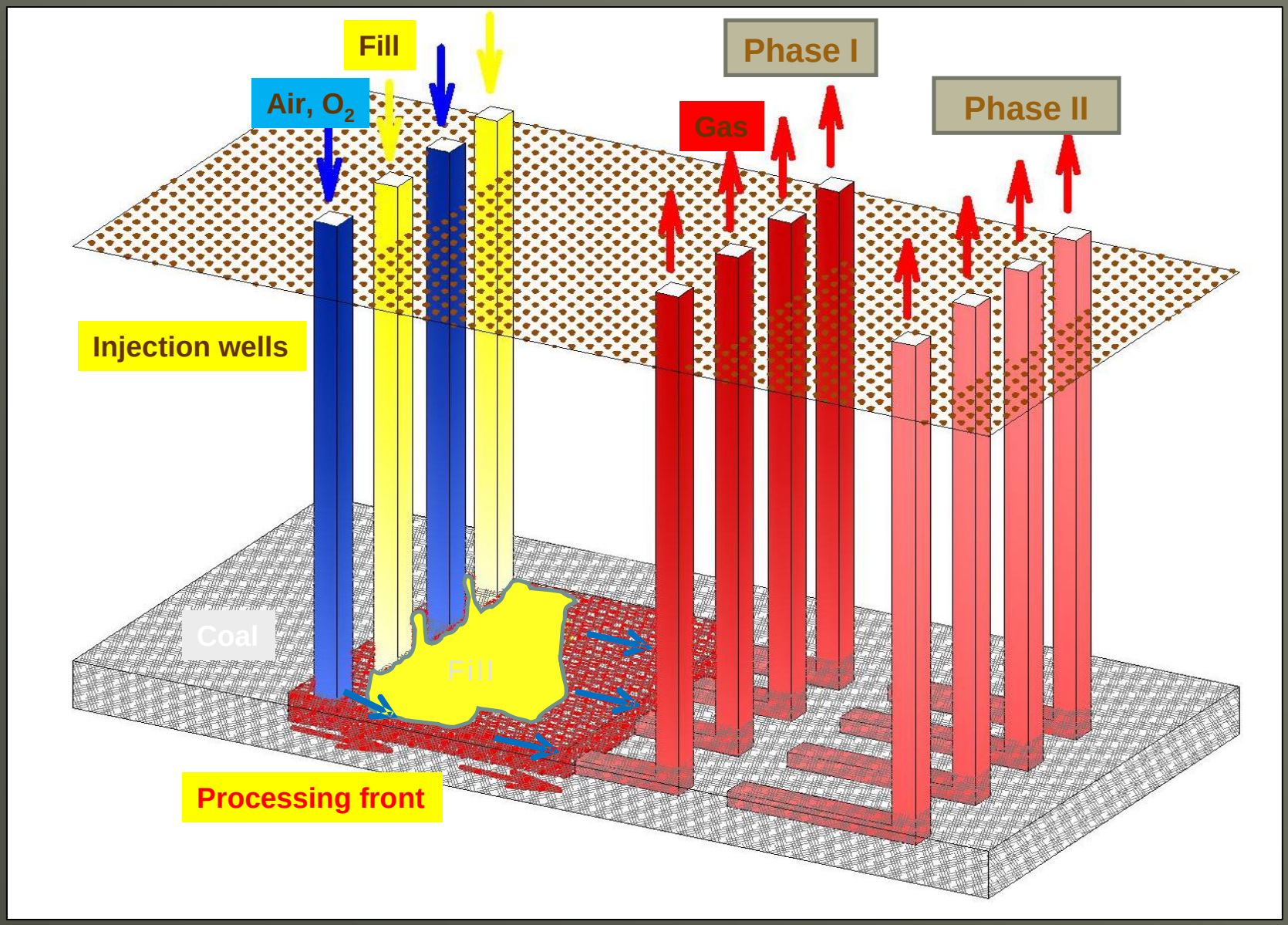
- Coal seam depth, thickness and dip
- Coal permeability
- Overburden properties
- Hydrogeology
- Drilling capabilities
- Required production volume
- Restrictions on subsidence and groundwater consumption



# Underground Coal Gasification for Europe



# UCG –Field Wells

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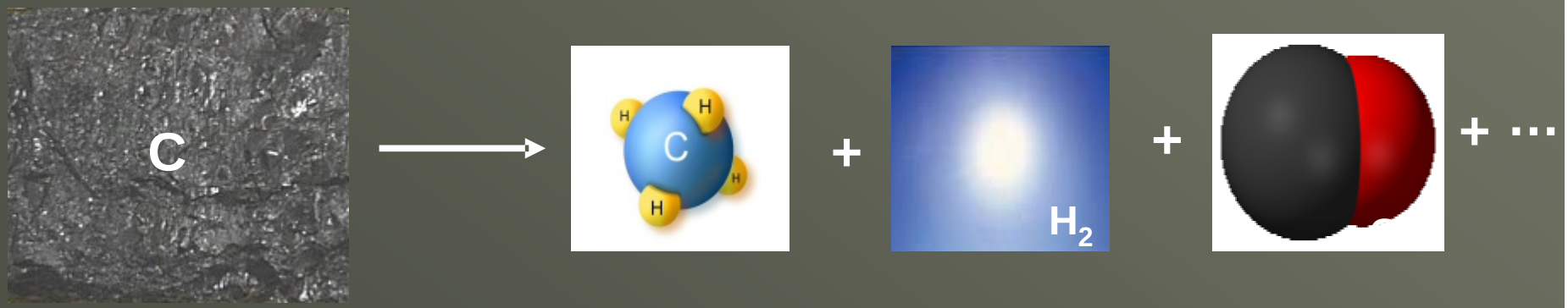
# Polish Activities in Underground Coal Gasification



# UCG in Poland

***Some important dates in connection with UCG in Poland***

| | |
|---|---|
| **1950 –** | **first UCG tests in laboratory** |
| **1953 –** | **underground experiments with coal gasification at mine Mars** |
| **Early 1980-s** | **some UCG modelling was conducted** |
| **2007** | **new experiments with UCG** |

# UCG in Poland - Current State

## Research and implementation of an innovative concept:

- **RFCS - EU Research project: HUGE (Hydrogen Oriented Underground Coal Gasification) – 11 Partners**
- **Pilot Project of Massive Production of Hydrogen from Coal Seams - The Private Investors**
- **Lignite gasification – KGHM activity**
- **UCG, CBM and $CO_2$– activity of *different business partners***

# UCG Project „HUGE”

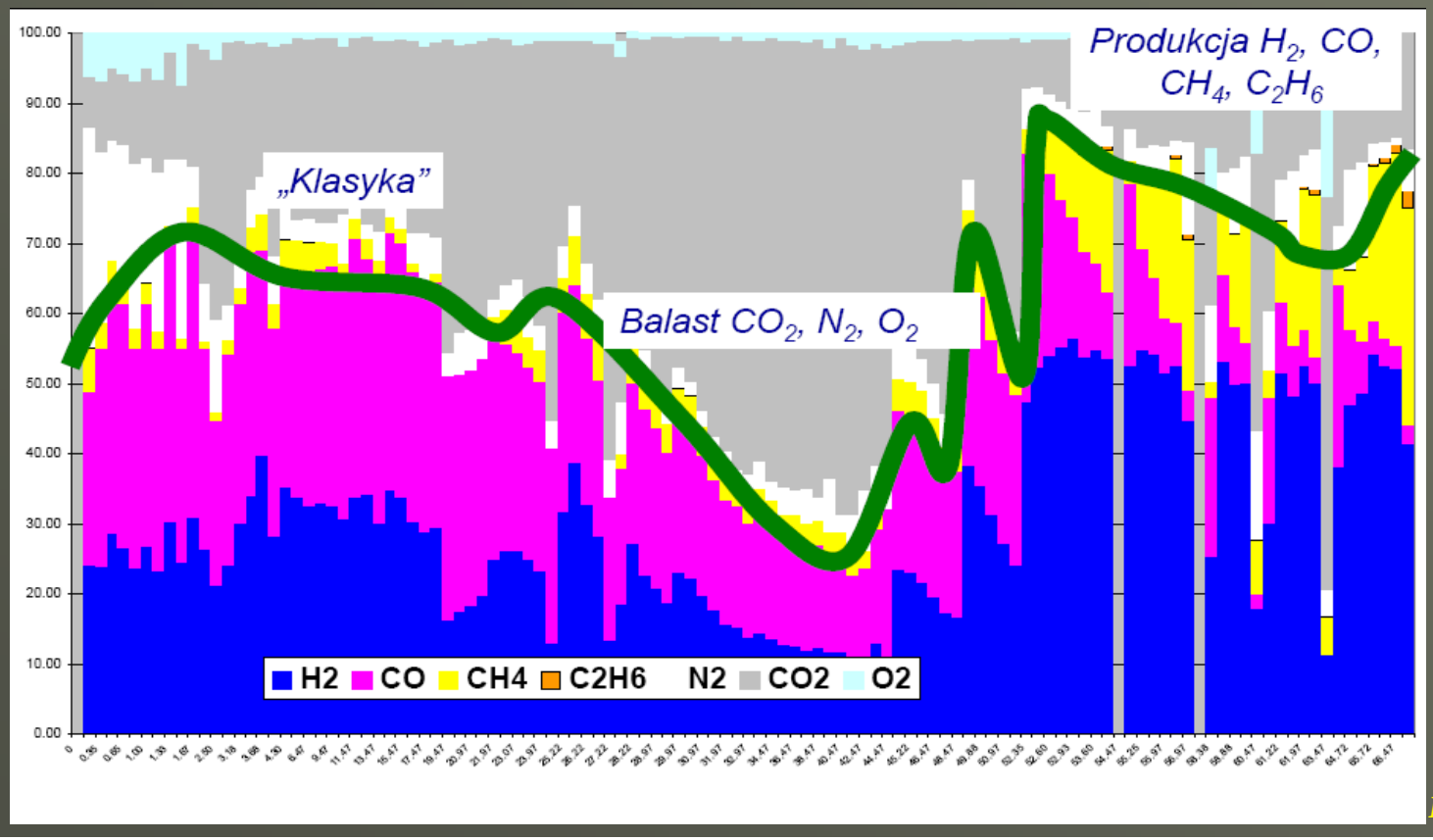
Hydrogen Oriented Underground Coal Gasification for Europe

- Starting date: 01. July 2007
- Project duration: 36 months
- Total costs: ca. 3.2 Mil. EURO

# Project summery

- The project explores the technology for hydrogen production through underground gasification of coal in a dynamic geo-reactor
- The process will be controlled through purposed dynamic changes in temperature and pressure of the reactants and products
- The project addresses CBM usage and $CO_2$ sequestration in coal deposits
- The locations of demonstration plants will be chosen through computer modelling and simulation – Silesia Region Poland

# Laboratory test – Coal Gasification (HUGE)




Source: GIG K-ce

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**Based on the mining concession which covers the area of 627 km$^2$ in Upper Silesia and the private investors**

# the PILOT PROJECT

**of Massive Production of Hydrogen from Coal Seams is started.**

The Super Daisy Shaft system and underground pyrolytic conversion of coal with steam and oxygen (without NOx) into synthesis gas, hydrogen & electric energy will be established.

Source: B. ZAKIEWICZ

# Production Capacity

## ONE SDS SYSTEM CAPACITY PRODUCTION

- 1 billion $m^3$ of synthesis gas per year
- 2.190 mln MWh electricity per year

## THOSE PRODUCTION REQUIRES

| | |
|---|---|
| Ø Coal | 1,942,000 tons/y |
| Ø Oxygen | 540,000 tons/y |
| Ø Water | 1,540,000 tons/y |

Source: B. ZAKIEWICZ

# The Polish Technology

## COMPLEX ENERGY EXTRACTION FROM COAL (CEEC)

**Technology we are implementing is offering:**

1. **Comprehensive extraction of 90% of original complex energy content in coal deposit**

2. **Massive extraction of CBM, saturated in pores and adsorbed by coal,** ***($CH_4$ is released and mobilized by micro-fracturing and dragging forces with the special system),***

3. **Massive production of high quality syngas, generated by pyrolitic underground processing and enhanced in surface reactors**

4. **Massive production of electric & heat energy from three streams of heat carriers:**
   - **water & steam stream**
   - **syngas stream**
   - **stream of chemical energy generated from produced gases**

5. **Massive production of Hydrogen, which is admixed in syngas with 40- 44%, which can be separated from the remaining gas components**

6. **Massive sequestration and utilization of $CO_2$**

7. **Massive waste utilization as fill material**

# UNDERGROUND ENERGY EXTRACTION FROM COAL HAS A WONDERFUL FUTURE!!!

Thank you !!!

Jan Palarski