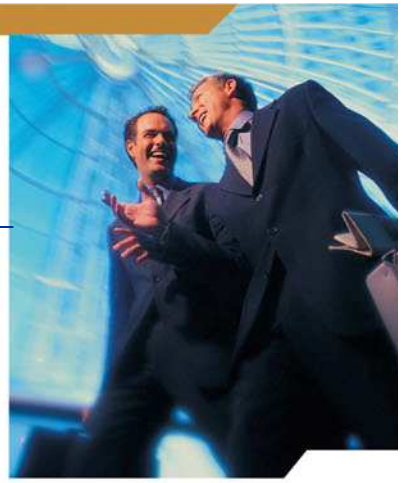
SUSTAINABLE LIFE CYCLE MANAGEMENT:

Evaluating the achievable benefits of extending technologies for uneconomical coal resources in South Africa



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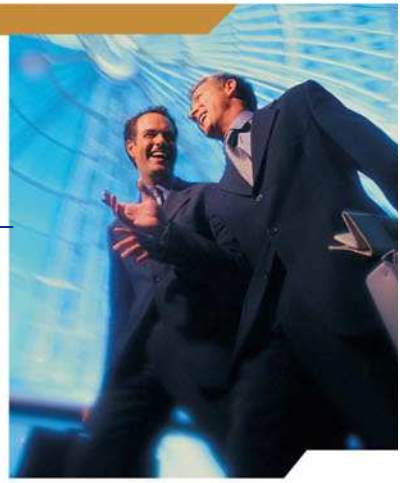
South African coal resources and reserves (next 30 years)



- **Basic definitions:**
  - Coal resources: coal deposits confirmed by a survey
  - Coal reserves: economically extractable coal resources

- **Basic assumptions:**
  - Presently estimated coal reserves level:
    - 27,000 – 30,000Mt
  - Coal production:
    - about 302Mt per annum
  - Adopted increase of production:
    - 5% per annum
  - Export of coal:
    - 70 – 90Mt per annum

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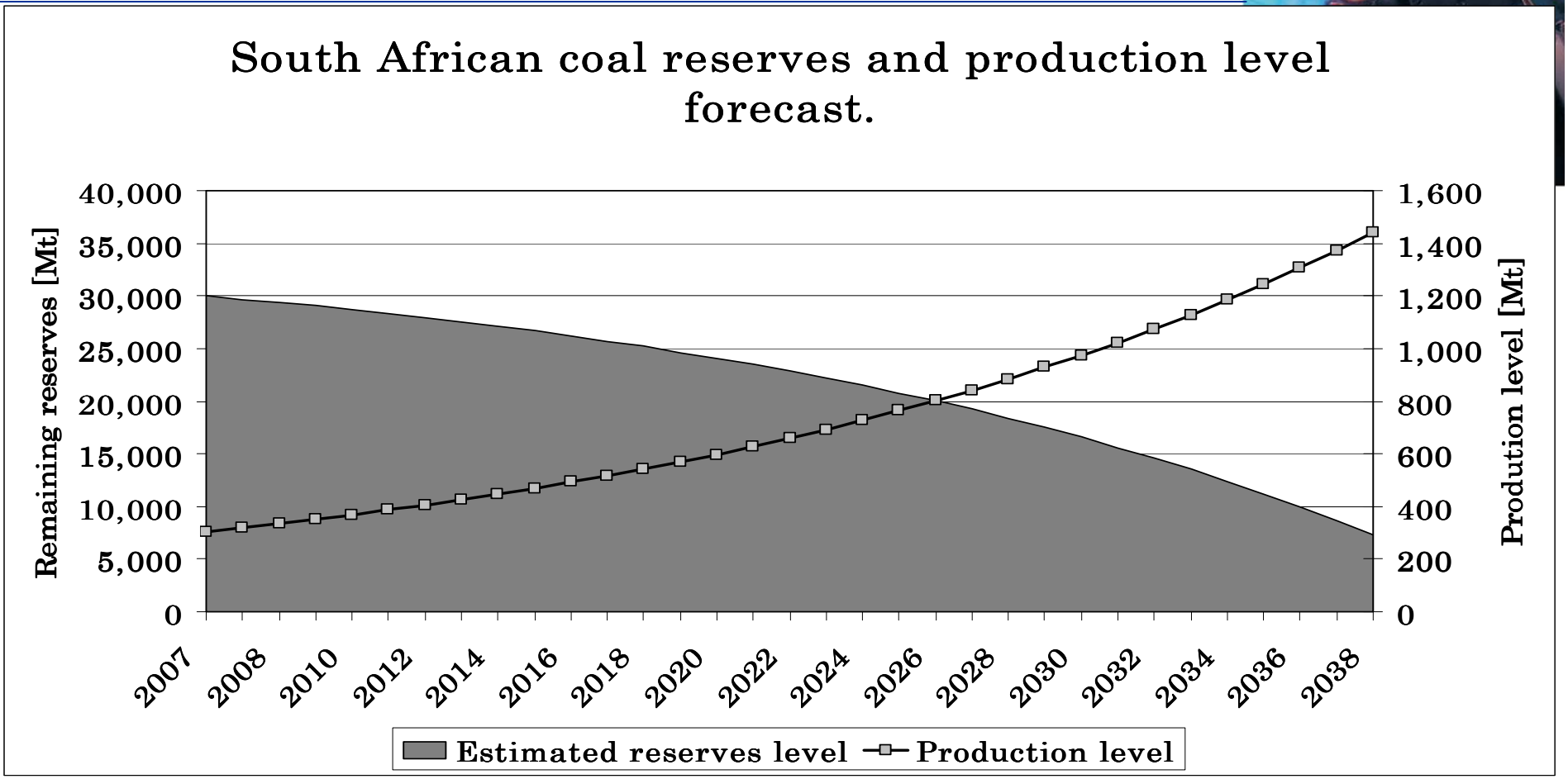
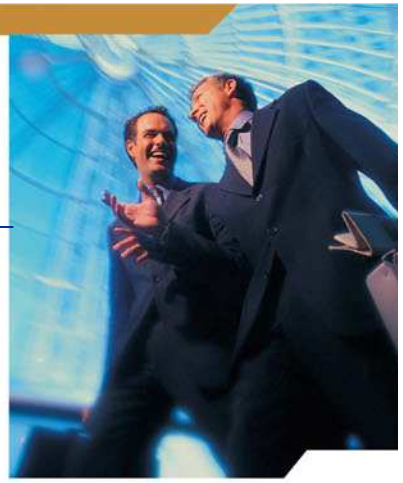


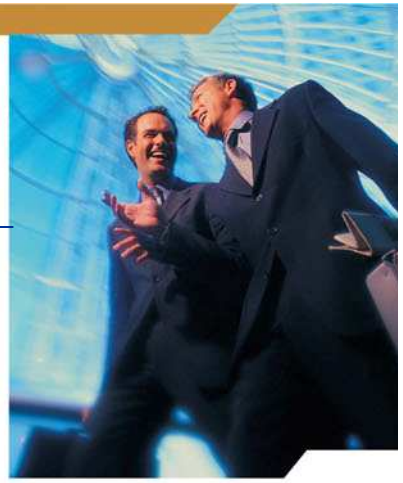
First observations

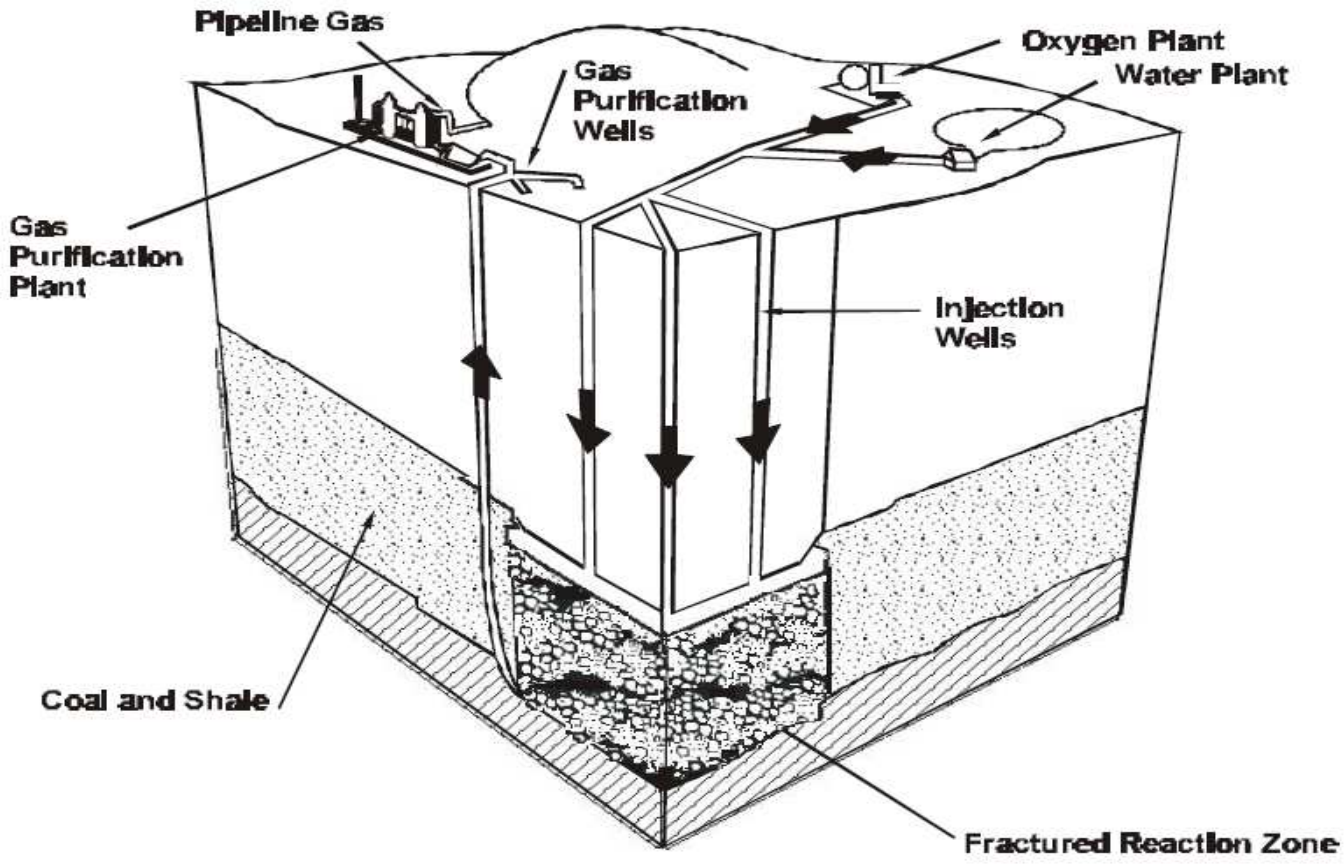


- **Coal resources are SA national, strategic reserves**
  - **Export of coal to be minimised**
- **Coal will remain the primary source of energy**

Technologies, such the underground coal gasification (UCG), allowing the *conversion of coal resources into reserves* should be exploited

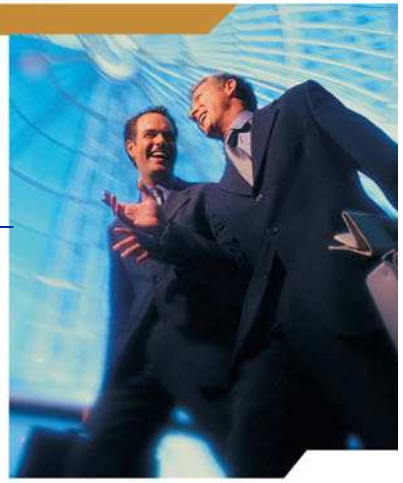
Principle of underground coal gasification (UCG)





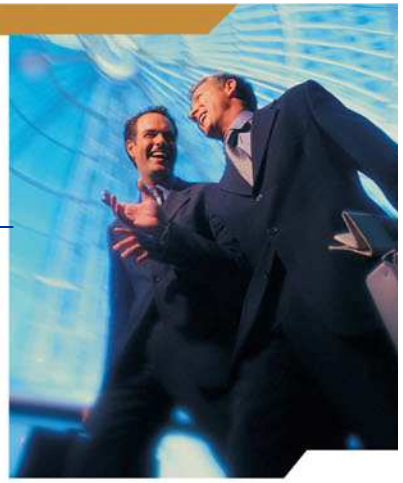
Source: US EPA (1999:4)

Generic benefits of the UCG technology



- **Accessibility**
  - Proven technology
- **Gaseous form of product**
  - Transferability
  - Convertibility
- **Environmentally friendly**
  - No air or water pollution
  - Ash remains in reaction zone
  - Lower CO_2 emission
- **Economic booster**
  - Extending longevity of mines
  - Areas not considered for a classic mining

UCG technology cost determination (cost determinant triangle)

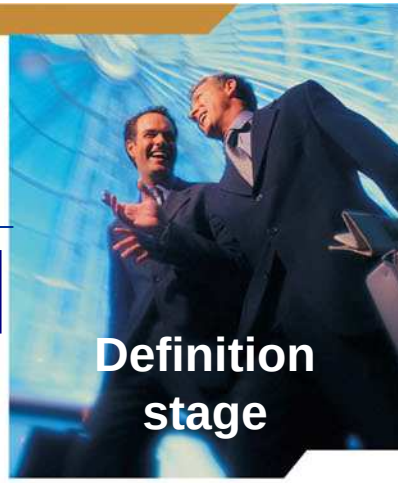


Purpose (demand)
heat, electric energy, steam or chemical conversion, synthesis

Resources available (geophysics of coal deposits)
depth, seam thickness, ash content

Exploitation and processing method
Oxygen or air as an agent, gas cleaning, transfer or local use, conversion or direct use

UCG cost benefits estimation model



Energy demand, gas demand, lifespan extension, etc.

"the need identification" – data frontloading

output: Gas quality determined

Coal seam thickness, depth and ash content

Matching the demanded quality

output: Technological "go/no go"

Feasibility stage

Invariable data (CAPEX, conversion ratio, gasifier availability, survey cost etc.

Invariable module & function module

output: Approximate costs

Functions input: geological data, transfer distances

Alternative solutions costs (electricity, liquid gas etc.

Direct benefits – economic tier

Externalities economy tier

Economic viability stage

External energy costs

output: UCG acceptable/unacceptable: final decision

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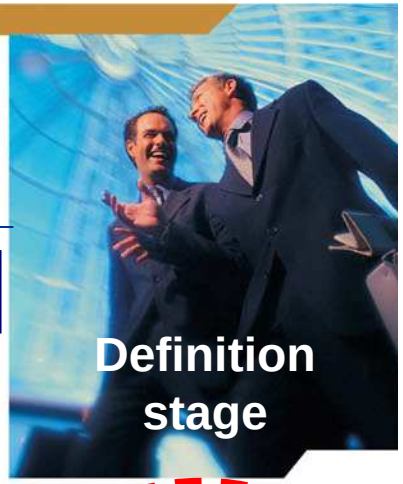

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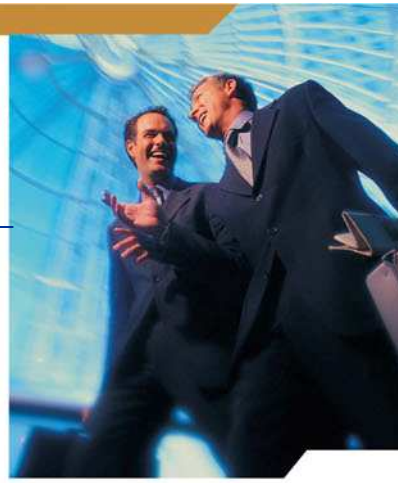
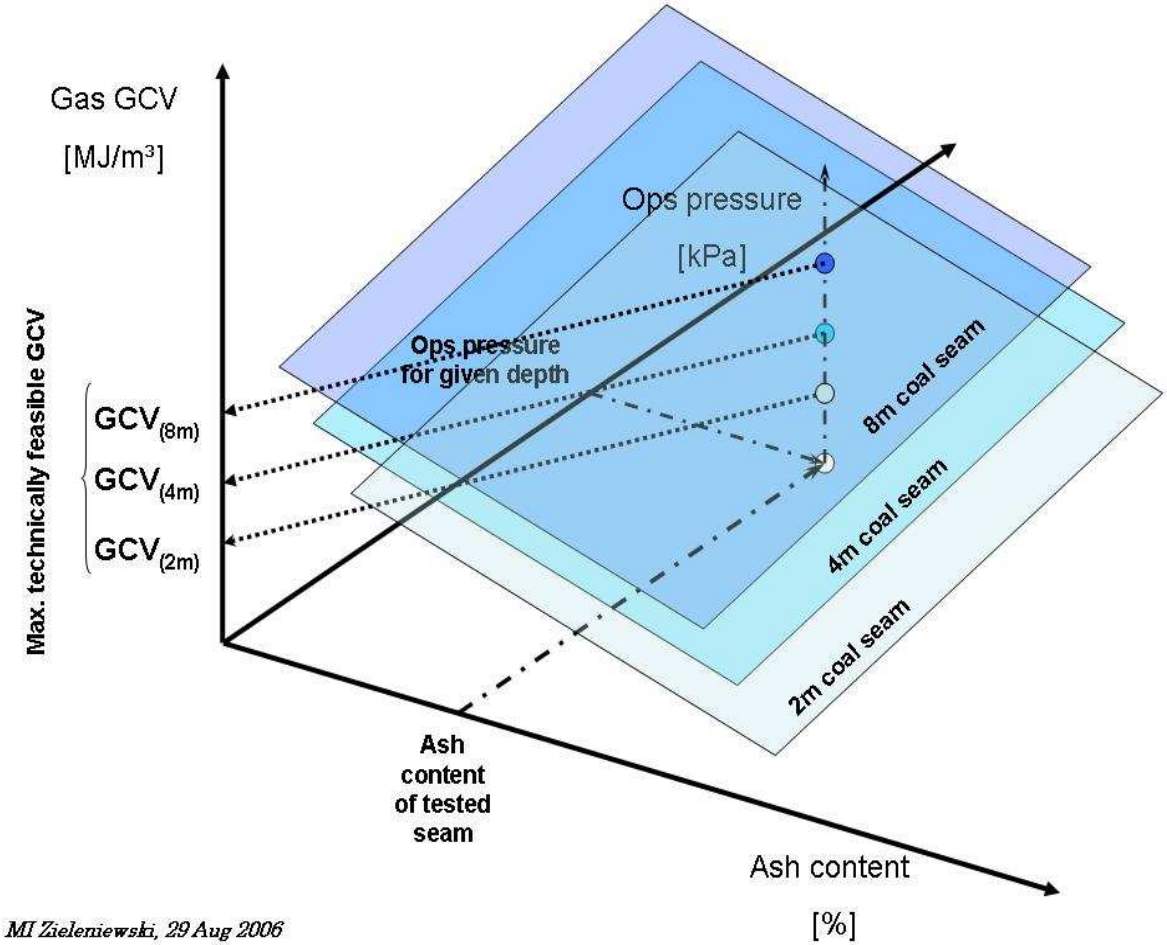
Relationships of feasibility stage test





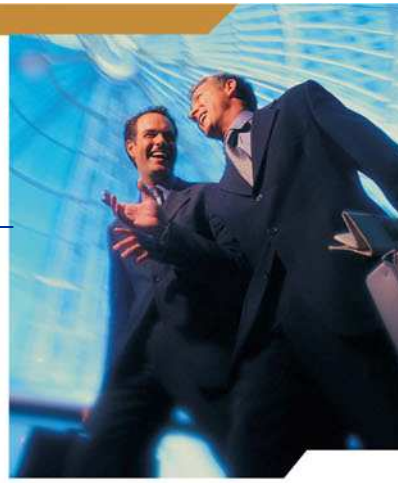
Geologic variables:

- **Coal ash content (X)**
- **Seam depth/operational pressure (Y)**
- **coal seam thickness**

Outcome:

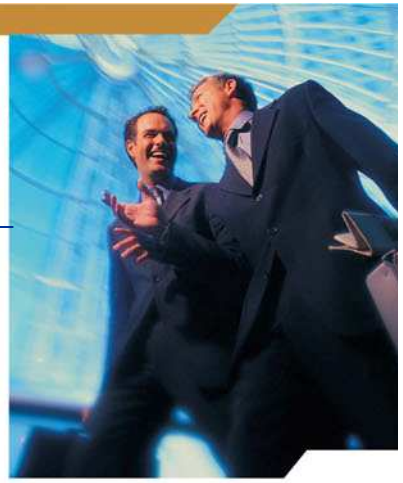
Potentially achievable GCV of the gas (Z)

Cost breakdown table



Exemplary cost breakdown for input variable sensitivity test (for 1Mt of coal/anum)				
Specification	**Unit**	**Item cost**	**Item**	**Total cost**
Initial costs:	[R*1,000]	35,000		35,000
In seam (DD) drilling	[R*1,000]	4,000		40,000
Well connecting piping	[R*1,000/m]	9.5	2500 m	237,500
Monitoring well drilling	[R*1,000/m]	0.3	16 wells	9,600
Vertical production wells	[R*1,000/m]	0.3	115 wells	57,500
Vertical injection wells	[R*1,000/m]	0.3	5 wells	2,500
Oxygen Plant capex & opex	[R*1,000]	1,122,643	1 plant	1,122,643
Total cost:	*[R*1,000]*			***1,504,743***
Oxygen/coal^{daf} yield	[m^3/tonne]	1,095.9		
DAF factor daf_f	[1]	0.705		
Oxygen/coal^{ar} yield	[m^3/tonne]	772.6	**Expected years:**	**10**
Total oxygen volume	[m^3*1,000]	7,726,434		
Oxygen unit cost	[R/m^3]	0.10		
Coal seam depth d_s	[m]	200	**Constant used:**	
Coal seam thickness *h*	[m]	2.5	ξ - gas/coal conversion =	
Coal ash A^{ad}	[%]	25.0	= 1,365 m^3/tonne	
Max.expected gas GCV_{tmx}	[MJ/m^3]	11.07	ρ - technical oxygen density =	
Expected gas volume V_{UCG}	[m^3]	1.37E+10	= 1.434 kg/m^3 @98.5% purity	
Total GCV (ex 1Mt coal)	[GJ]	1.51E+08		
Rand gas unit cost	***[R/GJ]***	***10.0***		

Sensitivity test for initial input data



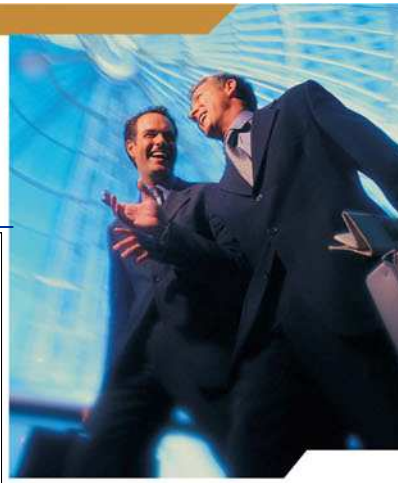
Case: "Ash: 25%, 3.5m seam"			*Delta*
Depth:	**100m**	**550m**	
Total costs	1,434,204	1,008,740	*-29.7%*
Gas unit cost	11.1	5.4	*-51.0%*
Case: "Ash: 25%, depth: 250m"			***Delta***
Thickness:	**0.5m**	**11m**	
Total costs	1,160,491	857,188	*-26.1%*
Gas unit cost	13.0	6.0	*-53.6%*
Case: "3.5m seam, depth: 250m"			***Delta***
Ash ^{ad}:	**15%**	**35%**	
Total costs	1,017,563	921,541	*-9.4%*
Gas unit cost	7.7	8.6	*11.0%*

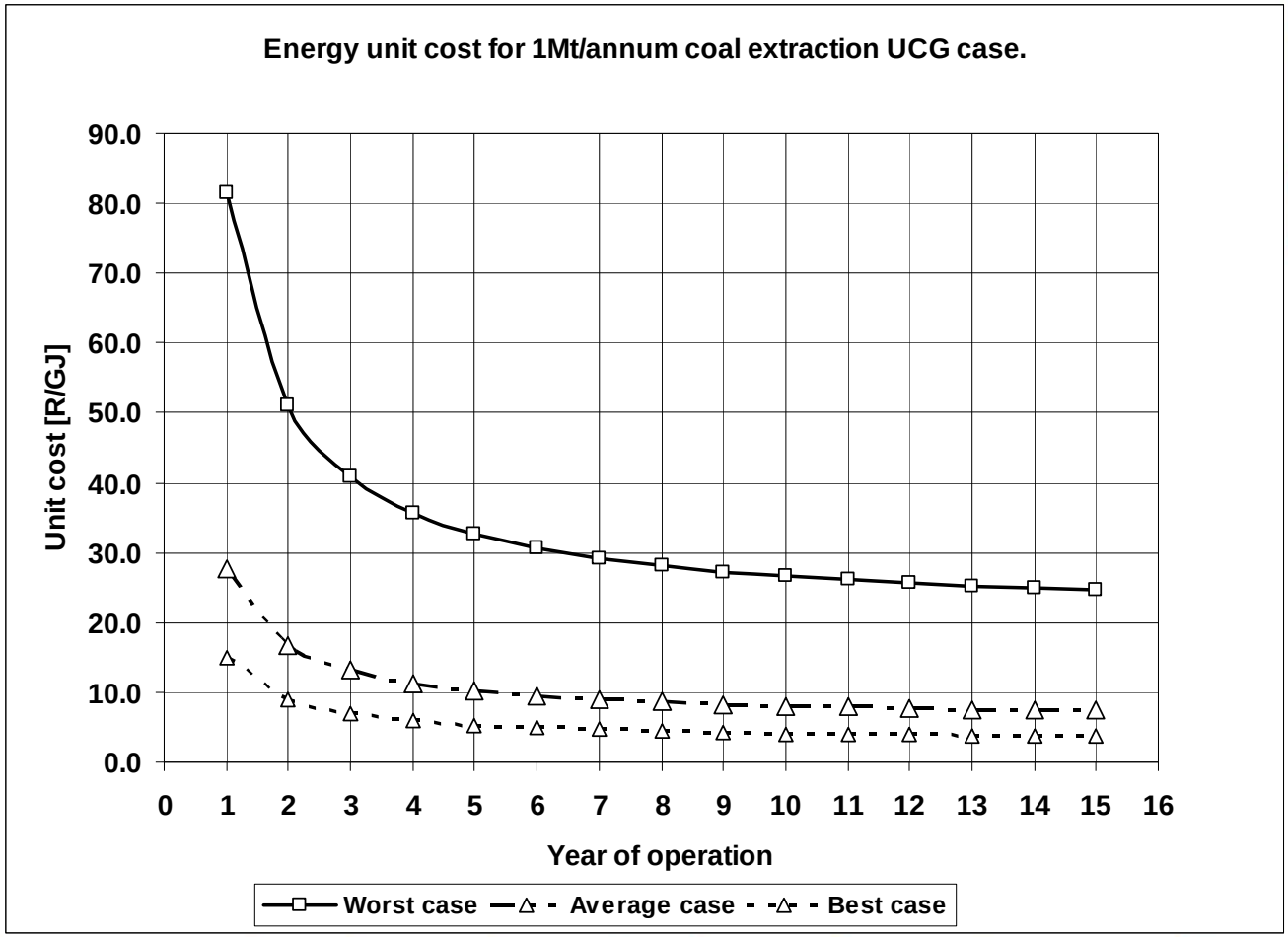
Test of one of variables with fixed, average value of remaining two determinants

Case: "Ash:15%, depth: 550m, 11m seam"			*Delta*
Total cost	**Best case**	924,731	
Gas unit cost		4.1	
Case: "Ash: 35%, depth: 100m, 0.5m seam"			
Total cost	**Worst case**	1,679,476	*81.6%*
Gas unit cost		26.6	*547.2%*

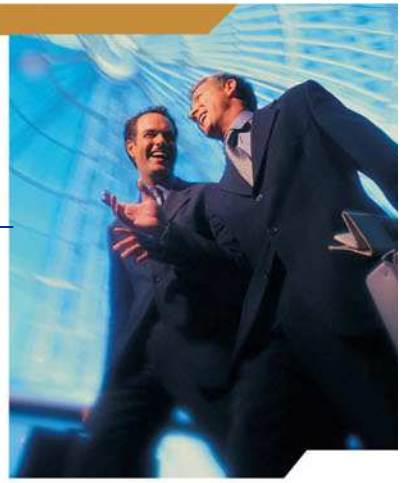
The extreme cases test

UCG life cycle levelled costs estimate





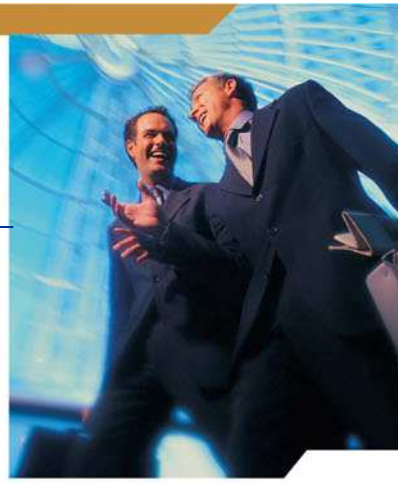
Externalities of energy costs (Extern-E)



- health effects of pollution (including life loss)
- ecological disturbance
- species loss
- landscape damage
- safety hazards

(…) typically not been reflected in the market price of energy, or considered by energy planners, and consequently have tended to be ignored. (…)The purpose of externalities research is to quantify damages in order to allow rational decisions to be made that weigh the benefits of actions to reduce externalities against the costs of doing so (PDC, 2003:12)

Externalities of energy costs (Extern-E)



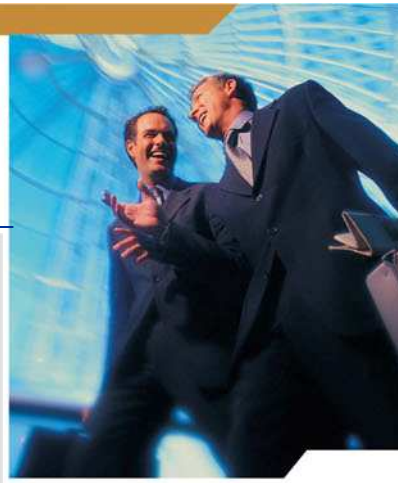
Cost of estimated externalities (*)		
Coal	0.120 - 0.193	R/MJ
Nuclear	0.005 - 0.010	R/MJ
Electricity	0.011 - 0.018	R/MJ
Paraffin (excluding deaths)	0.450	R/MJ
Paraffin (including deaths)	9.485	R/MJ
(*) Based on EU study and rate of ZAR9/Euro		

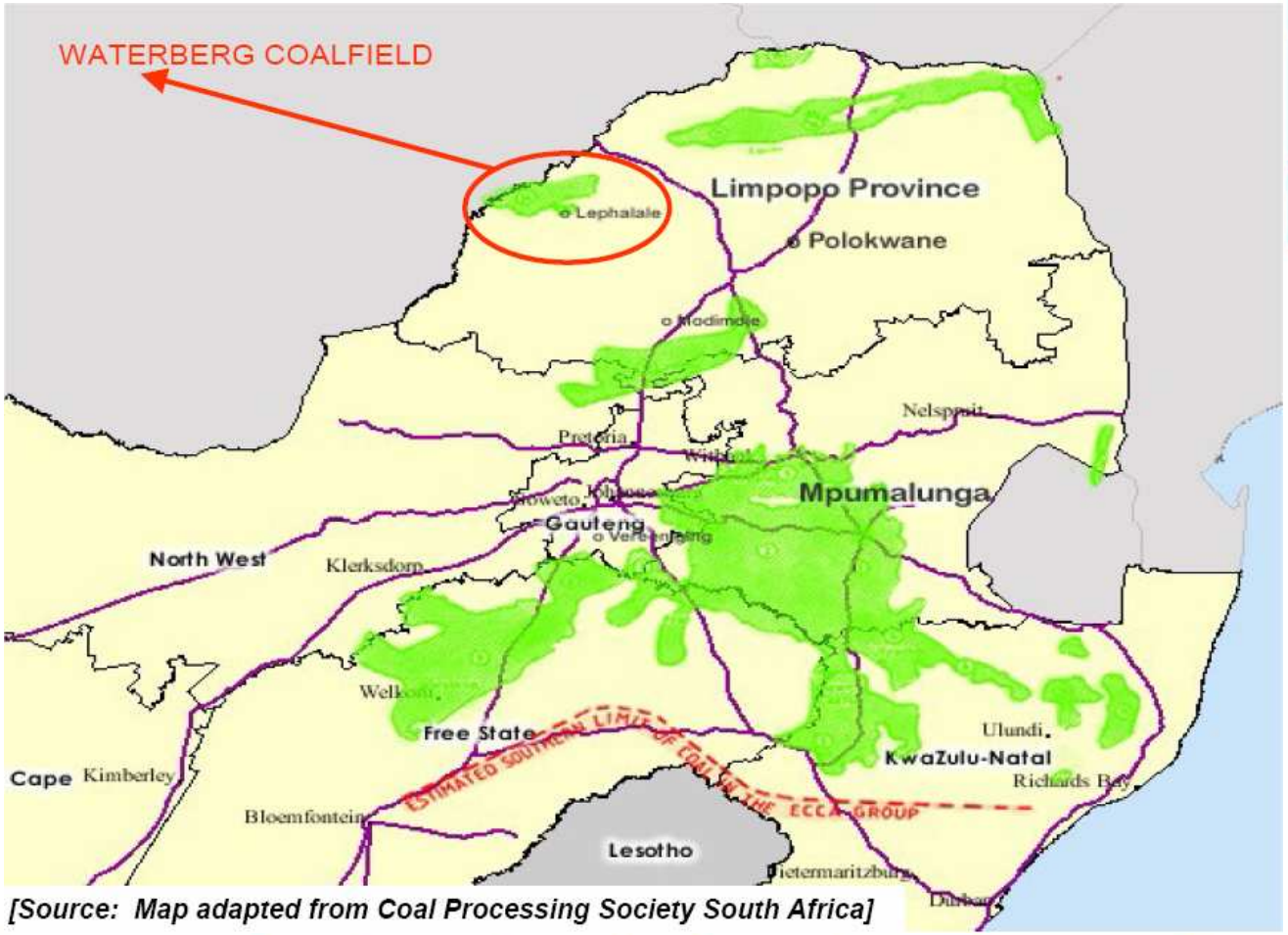
US EPA cited in PDC (2003:123)

"Estimates based on a national survey in 2001 and hospital records between 1996 and 2001 indicate that in South Africa:

- **80 000 children ingest paraffin every year;**
- **as a result, 40 000 children develop chemical pneumonia each year; and**
- **more than 200 000 children are injured or die from burn-related injuries, per year." (PDC, 2003:99)**

Generic model testing: Waterberg coalfield case





[Source: Map adapted from Coal Processing Society South Africa]

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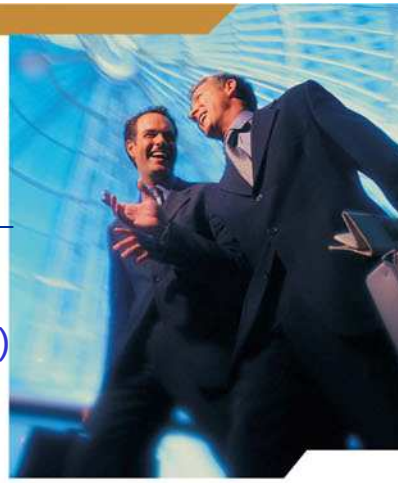


Feasibility stage (seam 2 geophysics):

- depth, *ds*:	290m	(maximum pressure of 2,150 kPa)
- thickness, *h:*	3.5m	
- ash (air dry), *Aad*:	24%	
Operational period (return on investment):	5 years	
Daily energy demand per household:	33kWh (9.3MJ)	
Oxygen Plant Capex + Opex	R690m	
Oxygen Plant capacity:	50,000m^3/h	
Gas network Capex	R2,000m	
Gas network Opex:	R150m	

Economic viability stage (results):

total costs:	R3,165m
energy unit (levelled) cost:	R0.048/MJ

For Capex of R10,000m (furnishing of the households with gas network outlets, gas meters and safe gas stoves, heaters, etc.) the gas unit cost is about 1/3 of the IP retail cost.

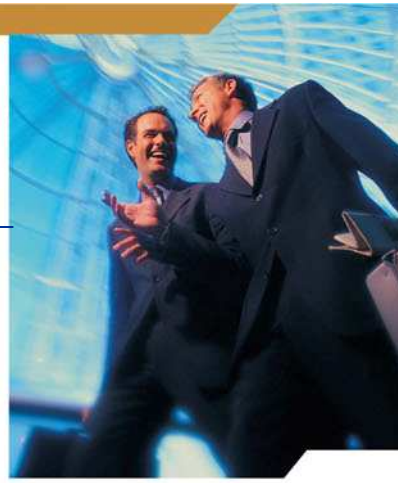
Total energy unit costs comparison

	Unit	Illuminating paraffin (IP)	UCG gas (R2bln Opex)	UCG gas (R10bln Opex)
Direct economic cost (retail price)	R/MJ	0.330	0.050	0.150
UCG externalities	R/MJ		0.055 (*)	0.045 (*)
Paraffin externalities (excluding deaths)	R/MJ	0.450		
Paraffin externalities (including deaths)	R/MJ	8.485		
Total unit cost	R/MJ	0.780 / 8.815	0.105	0.195

(*) - estimated as lower than coal (0.1-0.2 R/MJ) but within electricity range (0.01 - 0.02R/MJ)

Based on Waterberg Basin coal seam 2 geophysics

Conclusions based on UCG cost benefits model findings

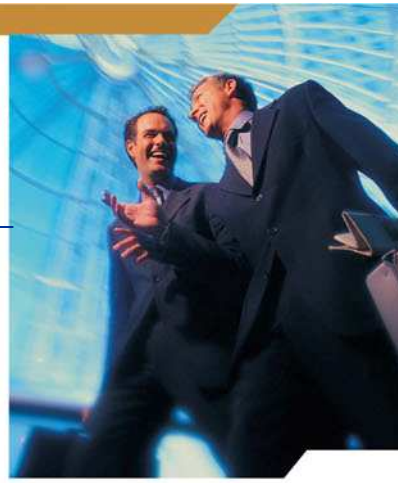


- The externality formulae allow the expression of environmental and national health losses as fairly well approximated costs illustrated in monetary terms, becoming more encouraging as an investment proposal

- If the “direct economy tier” presents a payback time of longer than five or seven years, additional benefits would appear in the form of declining medical and ecological expenditures during the much shorter time

- Future energy demands, as well as steadily rising prices of conventionally used agents, well allocated bonuses and preferential taxation should be used to encourage non-governmental investors to turn their attention and finances to UCG

South African on-going Sustainable Life Cycle Management research



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