Choosing The Best Coals in the Best Locations for UCG

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Which coals? Which locations?

- All coals may burn, but only some coals are amenable to UCG.
- A vast array of factors need to be taken into account in selecting viable sites for UCG.

- Evaluation:
  - Is it technically feasible?
  - Is it environmentally responsible?
  - Is it economically rational?

- This is NOT the same as asking “Can we try it? Will we get away with it? How much will we make?”

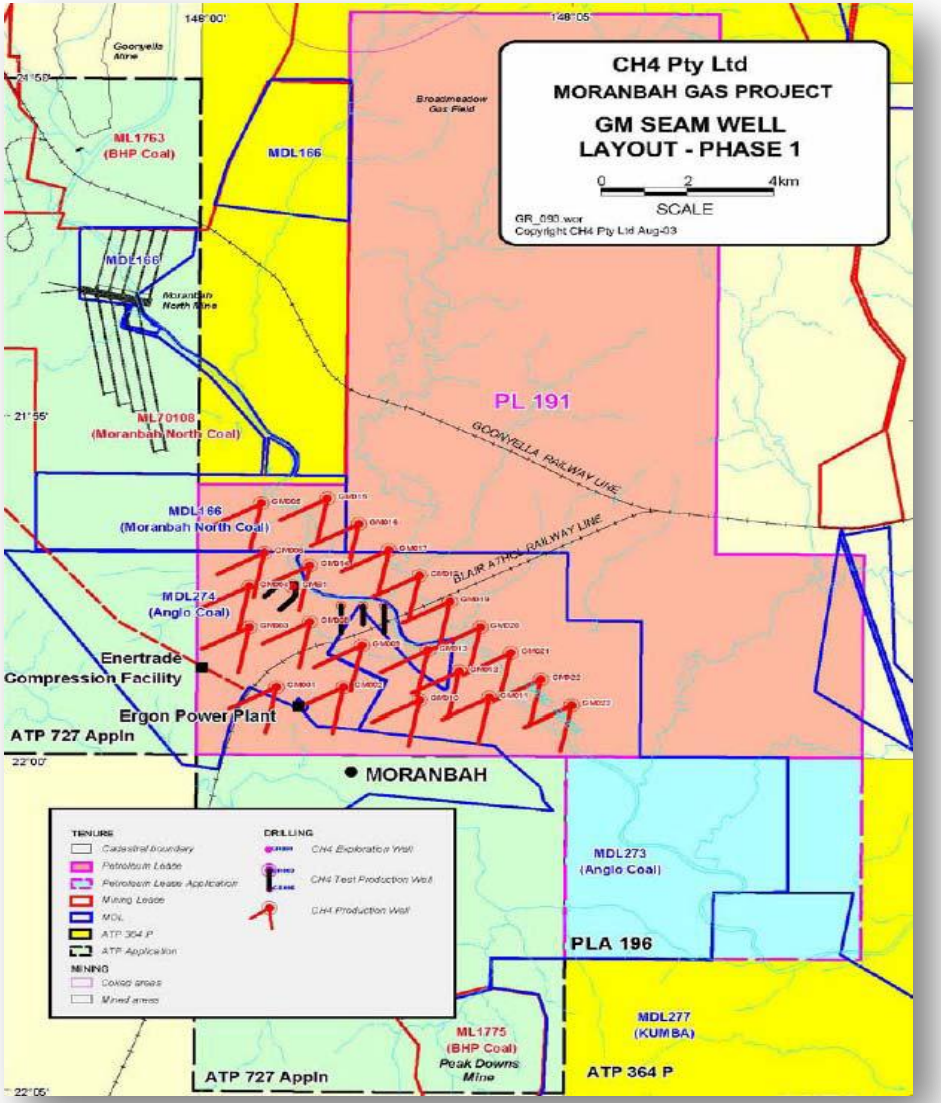
Selection Criteria

- A diverse range of coals and locations could be viable for UCG, especially as the technology evolves.
- During the evaluation process, many prospects fall by the wayside due to specific technical challenges or the simple arithmetic of costs and revenues.
- The goal is to find the ‘sweet spots’ where technical, environmental, and economic risks are minimised …. Because, even then, there are a lot of challenges ahead.

Technical Considerations

- **Surface land uses and conditions:** use restrictions, topography
  - e.g. UK UCG licenses

- **Field designs:** challenge to minimize surface impact while maximizing coal utilization



Technical Considerations

Depth of Coals:

- Shallow UCG has higher subsidence and fugitive emissions risk, and lower hydrostatic pressure.

- Going deeper means bigger rigs, more well control risk, more casing strings, larger surface footprint.

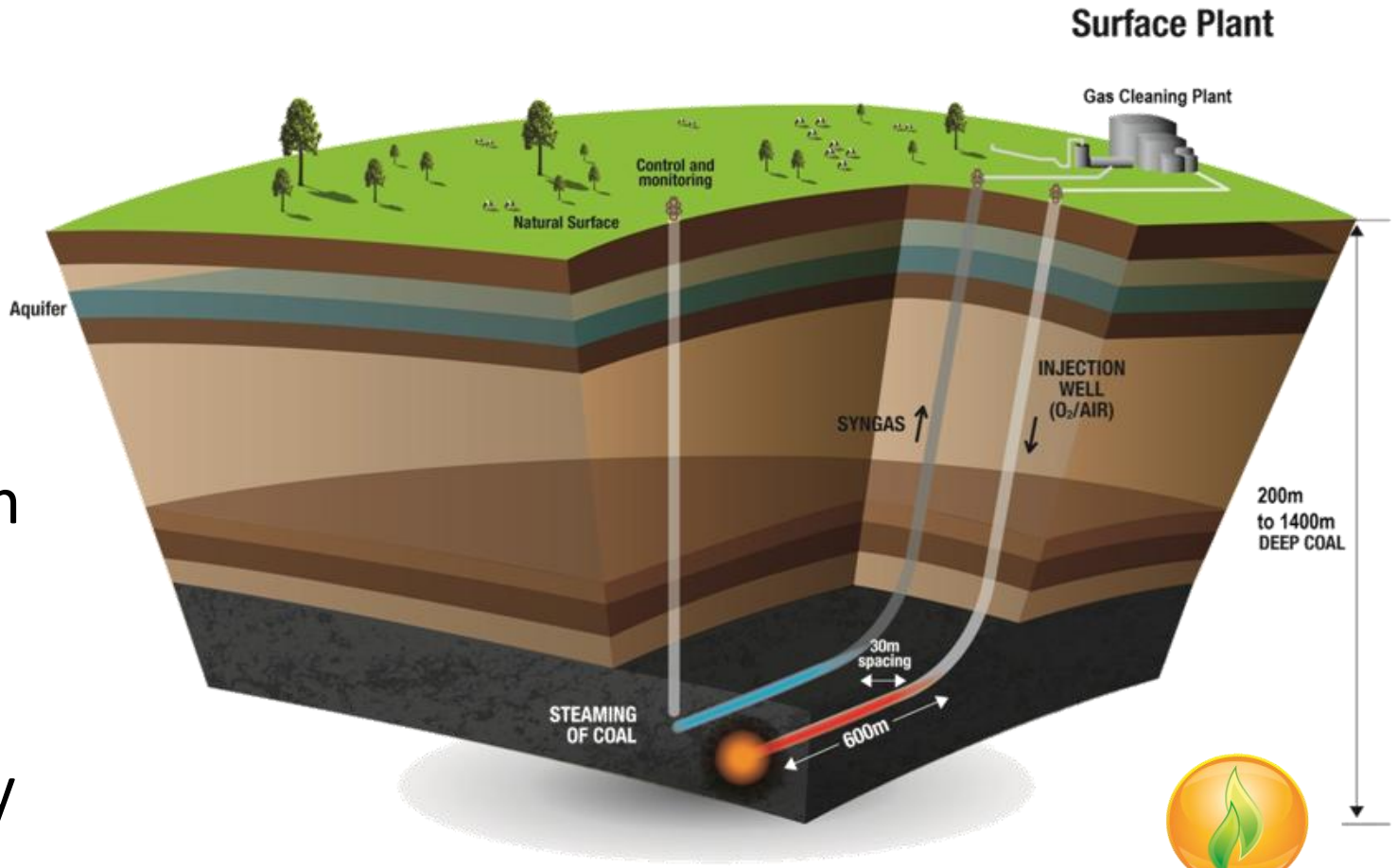
Technical Considerations

- **Faulting:** separation zones
- **Folding:** more difficult drilling, more complex geo-mechanics, more seismic required
- **Seam Inclination:** changes chamber design
- **Lithology:** beach sands, basalt, geo-mechanics impacting subsidence risk
- **Valued Aquifers:** well design requirements for sealing off, especially in light of temperature variance in well
- **Hydrogeology:** groundwater communication, permeability, monitoring, potential for reinjection of production water after cleaning.

Technical Considerations

Design of chambers:

- Verticals
- Laterals
- Injection systems
- Production wells
- Ignition
- Metallurgy



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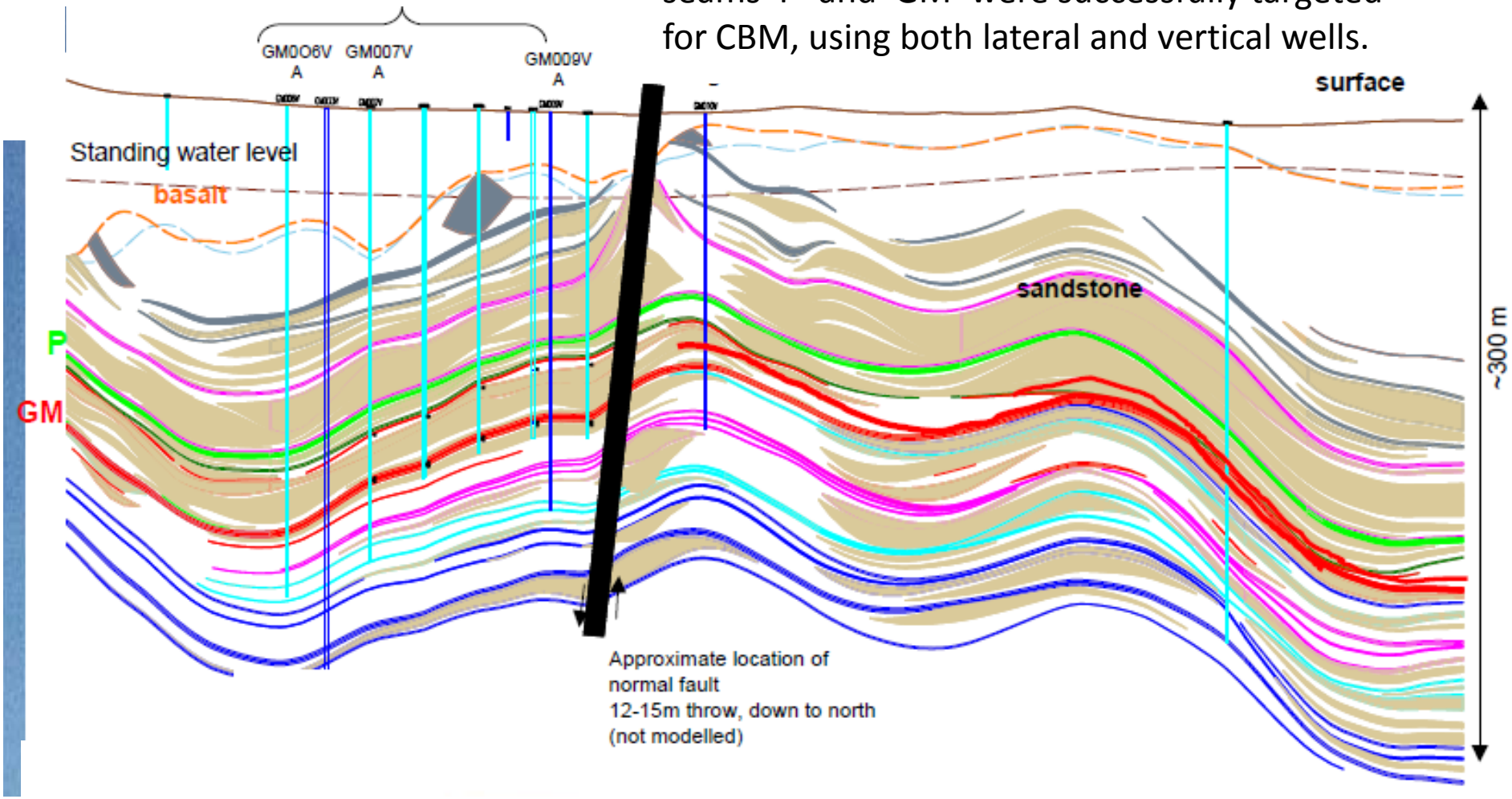
Technical Considerations

Confronting Reality:

The sub-surface can be a difficult space. Coal seams ‘P’ and ‘GM’ were successfully targeted for CBM, using both lateral and vertical wells.



Technical Considerations

- **Seam thickness:** impacts on both speed and risk of directional drilling, greater heat/energy loss from thin seams during gasification.
- **Coal chemistry**: contaminants create corrosive and erosive problems in the well, and safety and environmental issues at the surface.
- **Coal grade:** sub-bituminous high volatile is possibly preferable, but wide range is usable.

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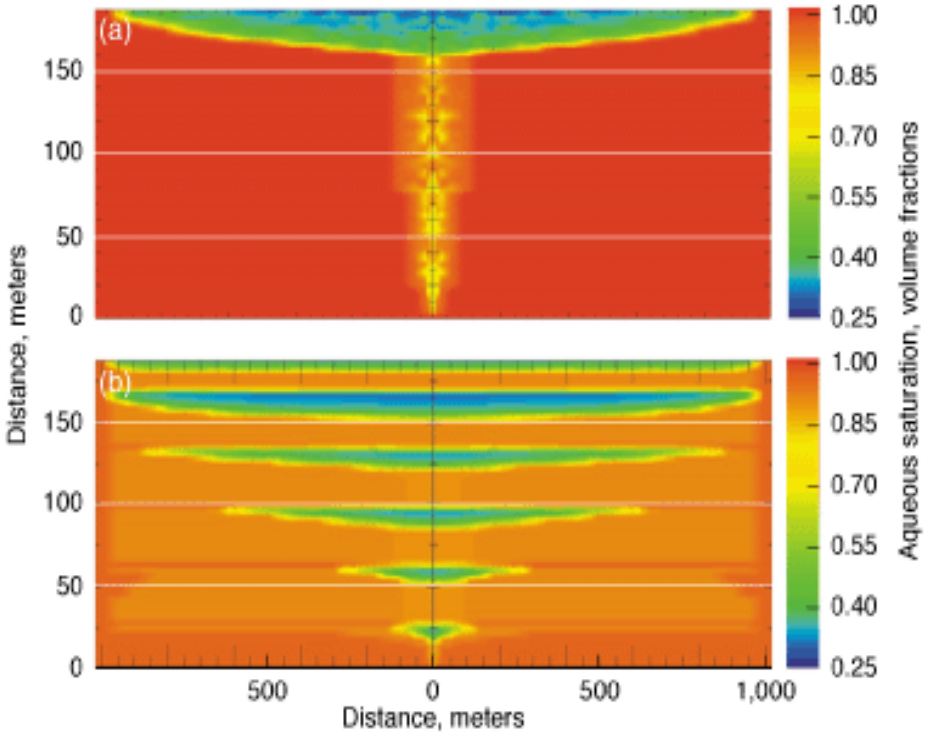
Technical Considerations

CO_2 Sequestration:

- This is still a very challenging issue.
- Maybe some unrealistic claims by UCG industry.
- Nevertheless, coal regions may offer sequestration opportunities, and UCG operators may be able to link CO_2 capture and storage more readily than some other energy producers.



Sequestration performance depends on the geology of the proposed sequestration site. (a) In an aquifer with no shale layers, the CO_2 plume rises quickly to the aquifer caprock, where it migrates laterally beneath this impermeable seal. (b) When shale units are present, they effectively retard the plume's vertical migration while promoting its lateral extension, thus enhancing the effects of solubility and mineral trapping.

"A Solution For Carbon Dioxide Overload"

https://www.llnl.gov/str/Johnson.html

Technical Considerations

- **Water make:** scrubbing, storage and disposal of contaminated production water, water rights.
- **Ex post:** de-commissioning of chambers, surface remediation, post-gasification monitoring.
- **Product markets and prices:** scale, plant and process design, risk, alliance partners.
- **Regulatory framework:** safety and environmental regulations, legal rights and obligations, approvals and licenses, sovereign risk.

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Environmental Considerations

- **Surface land uses and conditions:** industrial processing and pipelines, visual and amenity impact, subsidence to surface, dust, noise.
- **Subsidence:** surface impacts, opening path to higher aquifers, fugitive gases to surface.
- **Valued aquifers:** risk of impact on community water supplies, agriculture.

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Environmental Considerations

- **Hydrogeology:** water flow through chambers – leaching, contaminant movement, potential ultimate communication with valued aquifers.
- **Water make:** contaminated and saline water to surface, evaporation ponds, salt spread, water re-injection.
- **Coal chemistry:** CO_2 production per unit of energy produced, mercury, SOx, NOx, etc.

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Environmental Considerations

- **CO_2 sequestration:** crucial issue if sequestration is required, and could be a determining factor on whether UCG projects will be able to progress in some jurisdictions.
- **Ex post:** need to develop protocols for de-commissioning, surface remediation, monitoring, and could face future requirements for financial guarantees or funds in trust.

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Economic Considerations

Economic modeling can provide a useful tool for considering some of the complexities of UCG prospects, as it tends to narrow the thinking to:

- risk,
- revenue,
- capex, and
- opex.

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Sample Coals

Moisture	Ash	Volatiles	Fixed Carbon	Calorific Value	Sulphur
10.5%	10.9%	30.5%	56.1%	30 MJ/kg	0.5%
26.6%	4.14%	34.4%	34.9%	15.2 – 18.3 MJ/kg	0.26%
9.5 – 14.4%	11.3 – 12.7%	25.1 – 30.7%	51.5 – 57%	27 MJ/kg	n/a
2.5%	28.5%	30.6%	37.4%	22.7 MJ/kg	0.1 – 1%

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syncrude	
Production	2500	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Air	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

Figures are for exposition only, and do not necessarily represent actual cases.

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	1	
Seam Thickness	20	m
Panel Length	600	m
Seam Depth	1200	m
Separation Distance	30	m

Production Parameters		
Oxidant	Air	
Syngas Flow Rate	29045	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

Economic Modelling

OUTPUTS		
Syngas	1 coal at 1200 m depth in 20 m thick seam	
Breakeven Price	$2.89	$/GJ
Heating Value	6.6	MJ/kg
Panel Total Energy	7.7	PJ
Panel BOE Energy	1,258,239	bbl crude
Panel Life	778	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$751
REVENUE	$447
OPEX	$262
Simple Payback Yr	4.1

UCG Facility	$ m
CAPEX	$120
REVENUE	$209
OPEX	$209

Assumptions		
Product Data		
Electricity	$/MWh	$40
Syncrude	$/tonne	$530
Feedstock Data		
Syngas (Air Blown)	$/tonne	$19.08

Figures are for exposition only, and do not necessarily represent actual cases.

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syngas (Clean)	
Production	5000	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Oxygen	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

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INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	1	
Seam Thickness	20	m
Panel Length	600	m
Seam Depth	1200	m
Separation Distance	30	m

Production Parameters		
Oxidant	Oxygen	
Syngas Flow Rate	9438	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

Economic Modelling

OUTPUTS		
Syngas	1 coal at 1200 m depth in 20 m thick seam	
Breakeven Price	$1.78	$/GJ
Heating Value	14.5	MJ/kg
Panel Total Energy	8.0	PJ
Panel BOE Energy	1,300,980	bbl crude
Panel Life	367	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$299
REVENUE	$123
OPEX	$85
Simple Payback Yr	7.8

UCG Facility	$ m
CAPEX	$42
REVENUE	$99
OPEX	$99

Assumptions		
Product Data		
Sulphur	$/tonne	$100
Syngas (Clean)	$/tonne	$83
Feedstock Data		
Electricity	$/MWh	$40.00
Syngas (O2 Blown)	$/tonne	$25.72

Figures are for exposition only, and do not necessarily represent actual cases.

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syncrude	
Production	2500	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Air	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	2	
Seam Thickness	5.5	m
Panel Length	600	m
Seam Depth	900	m
Separation Distance	30	m

Production Parameters		
Oxidant	Air	
Syngas Flow Rate	29045	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

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Economic Modelling

OUTPUTS		
Syngas	2 coal at 900 m depth in 5.5 m thick seam	
Breakeven Price	$3.77	$/GJ
Heating Value	7.8	MJ/kg
Panel Total Energy	2.1	PJ
Panel BOE Energy	349,301	bbl crude
Panel Life	182	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$751
REVENUE	$447
OPEX	$362
Simple Payback Yr	8.7

UCG Facility	$ m
CAPEX	$90
REVENUE	$323
OPEX	$323

Assumptions		
Product Data		
Electricity	$/MWh	$40
Syncrude	$/tonne	$530
Feedstock Data		
Syngas (Air Blown)	$/tonne	$29.51

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syngas (Clean)	
Production	5000	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Oxygen	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	2	
Seam Thickness	5.5	m
Panel Length	600	m
Seam Depth	900	m
Separation Distance	30	m

Production Parameters		
Oxidant	Oxygen	
Syngas Flow Rate	9438	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

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Economic Modelling

OUTPUTS		
Syngas	2 coal at 900 m depth in 5.5 m thick seam	
Breakeven Price	$2.84	$/GJ
Heating Value	15.9	MJ/kg
Panel Total Energy	2.2	PJ
Panel BOE Energy	359,056	bbl crude
Panel Life	92	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$299
REVENUE	$123
OPEX	$139
Simple Payback Yr	N/A

UCG Facility	$ m
CAPEX	$32
REVENUE	$173
OPEX	$173

Assumptions		
Product Data		
Sulphur	$/tonne	$100
Syngas (Clean)	$/tonne	$83
Feedstock Data		
Electricity	$/MWh	$40.00
Syngas (O2 Blown)	$/tonne	$45.25

Figures are for exposition only, and do not necessarily represent actual cases.

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syncrude	
Production	2500	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Air	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	3	
Seam Thickness	5	m
Panel Length	600	m
Seam Depth	500	m
Separation Distance	30	m

Production Parameters		
Oxidant	Air	
Syngas Flow Rate	29045	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

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Economic Modelling

OUTPUTS		
Syngas	3 coal at 500 m depth in 5 m thick seam	
Breakeven Price	$4.56	$/GJ
Heating Value	5.5	MJ/kg
Panel Total Energy	1.5	PJ
Panel BOE Energy	247,603	bbl crude
Panel Life	184	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$751
REVENUE	$447
OPEX	$319
Simple Payback Yr	5.8

UCG Facility	$ m
CAPEX	$57
REVENUE	$274
OPEX	$274

Assumptions		
Product Data		
Electricity	$/MWh	$40
Syncrude	$/tonne	$530
Feedstock Data		
Syngas (Air Blown)	$/tonne	$25.02

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syngas (Clean)	
Production	5000	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Oxygen	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	3	
Seam Thickness	5	m
Panel Length	600	m
Seam Depth	500	m
Separation Distance	30	m

Production Parameters		
Oxidant	Oxygen	
Syngas Flow Rate	9438	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

Figures are for exposition only, and do not necessarily represent actual cases.

Economic Modelling

OUTPUTS

Syngas	3 coal at 500 m depth in 5 m thick seam	
Breakeven Price	$3.12	$/GJ
Heating Value	12.8	MJ/kg
Panel Total Energy	1.6	PJ
Panel BOE Energy	257,230	bbl crude
Panel Life	82	Days

OUTPUTS

Surface Facilities	$ m
CAPEX	$299
REVENUE	$123
OPEX	$124
Simple Payback Yr	N/A

UCG Facility	$ m
CAPEX	$20
REVENUE	$153
OPEX	$153

Assumptions

Product Data		
Sulphur	$/tonne	$100
Syngas (Clean)	$/tonne	$83
Feedstock Data		
Electricity	$/MWh	$40.00
Syngas (O2 Blown)	$/tonne	$39.91

Figures are for exposition only, and do not necessarily represent actual cases.

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syncrude	
Production	2500	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Air	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

Figures are for exposition only, and do not necessarily represent actual cases.

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	4	
Seam Thickness	20	m
Panel Length	600	m
Seam Depth	500	m
Separation Distance	300	m
Production Parameters		
Oxidant	Air	
Syngas Flow Rate	29045	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

Economic Modelling

OUTPUTS		
Syngas	4 coal at 500 m depth in 20 m thick seam	
Breakeven Price	$1.11	$/GJ
Heating Value	9.2	MJ/kg
Panel Total Energy	68.0	PJ
Panel BOE Energy	11,112,917	bbl crude
Panel Life	4925	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$751
REVENUE	$447
OPEX	$178
Simple Payback Yr	2.8

UCG Facility	$ m
CAPEX	$57
REVENUE	$112
OPEX	$112

Assumptions		
Product Data		
Electricity	$/MWh	$40
Syncrude	$/tonne	$530
Feedstock Data		
Syngas (Air Blown)	$/tonne	$10.24

Figures are for exposition only, and do not necessarily represent actual cases.

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Economic Modelling

INPUTS SURFACE FACILITIES

Product	Enter Data	
Product Class	Feedstock	
Product Type	Syngas (Clean)	
Production	5000	tpd
CO2 Disposal	Vented	
Gasification Location	Underground	
Oxidant	Oxygen	

Enter Surface Facility Data in table above

Click here to calculate UCG flowrate requirements

INPUTS UCG This calculates Raw Syngas Cost and HHV

Coal Seam	Enter Data	
Coal Type	4	
Seam Thickness	20	m
Panel Length	600	m
Seam Depth	300	m
Separation Distance	30	m

Production Parameters		
Oxidant	Oxygen	
Syngas Flow Rate	9438	tpd

Enter Coal Seam and Prodn Parameters in table above

Click here to calculate UCG Syngas Costs

Figures are for exposition only, and do not necessarily represent actual cases.

Economic Modelling

OUTPUTS		
Syngas	4 coal at 300 m depth in 20 m thick seam	
Breakeven Price	$0.85	$/GJ
Heating Value	14.7	MJ/kg
Panel Total Energy	6.9	PJ
Panel BOE Energy	1,130,926	bbl crude
Panel Life	314	Days

OUTPUTS	
Surface Facilities	$ m
CAPEX	$299
REVENUE	$123
OPEX	$49
Simple Payback Yr	4.0

UCG Facility	$ m
CAPEX	$15
REVENUE	$48
OPEX	$48

Assumptions		
Product Data		
Sulphur	$/tonne	$100
Syngas (Clean)	$/tonne	$83
Feedstock Data		
Electricity	$/MWh	$40.00
Syngas (O2 Blown)	$/tonne	$12.47

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Thank you

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