WHEN AND WHY AN UCG PROJECT CAN BE SUCCESFULLY IMPLEMENTED – A fly-over of the 50 MWe THEUNISSEN UCG project in South-Africa

AFRICARY
African Carbon Energy

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31st International Pittsburgh Coal Conference, October 2014

Roadmap for the presentation

*Introduction to **AFRICAN CARBON ENERGY** and its flagship*

50 MWe Theunissen UCG Project

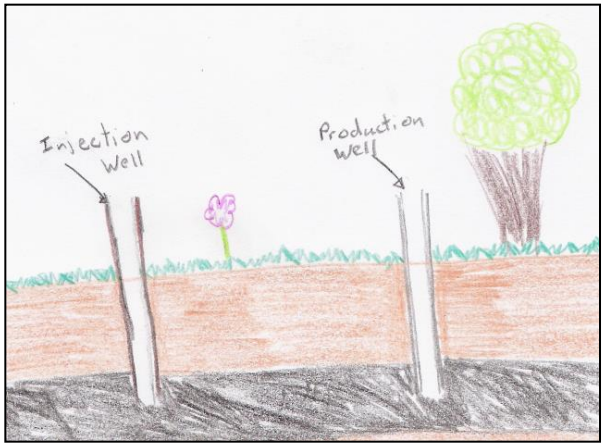
- ***U** - Underground technology and getting into the coal seam*
- ***C** - "Coalology" (coal and geology)*
- ***G** - Gasification science*

Objective:** **AFRICARY will commercialize UCG as a next generation mining and energy technology for South Africa

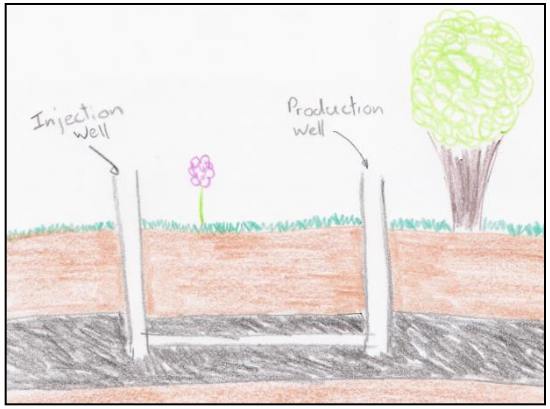
How does UCG work?

Find the coal

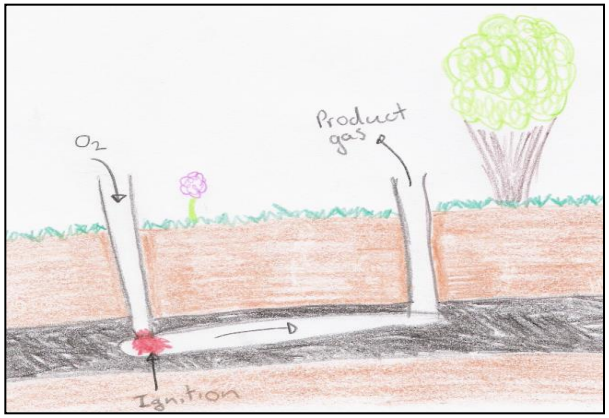
Drill the boreholes



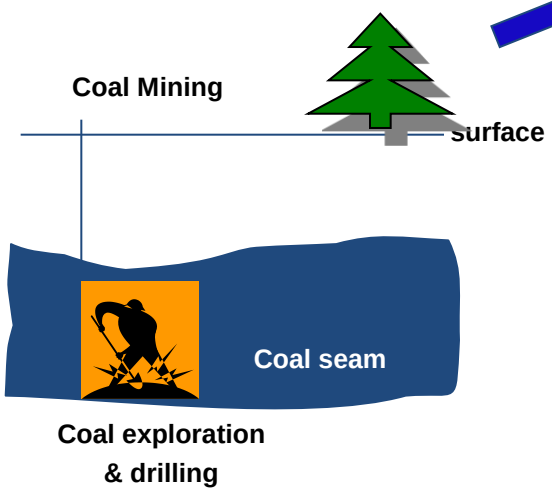
Link the boreholes

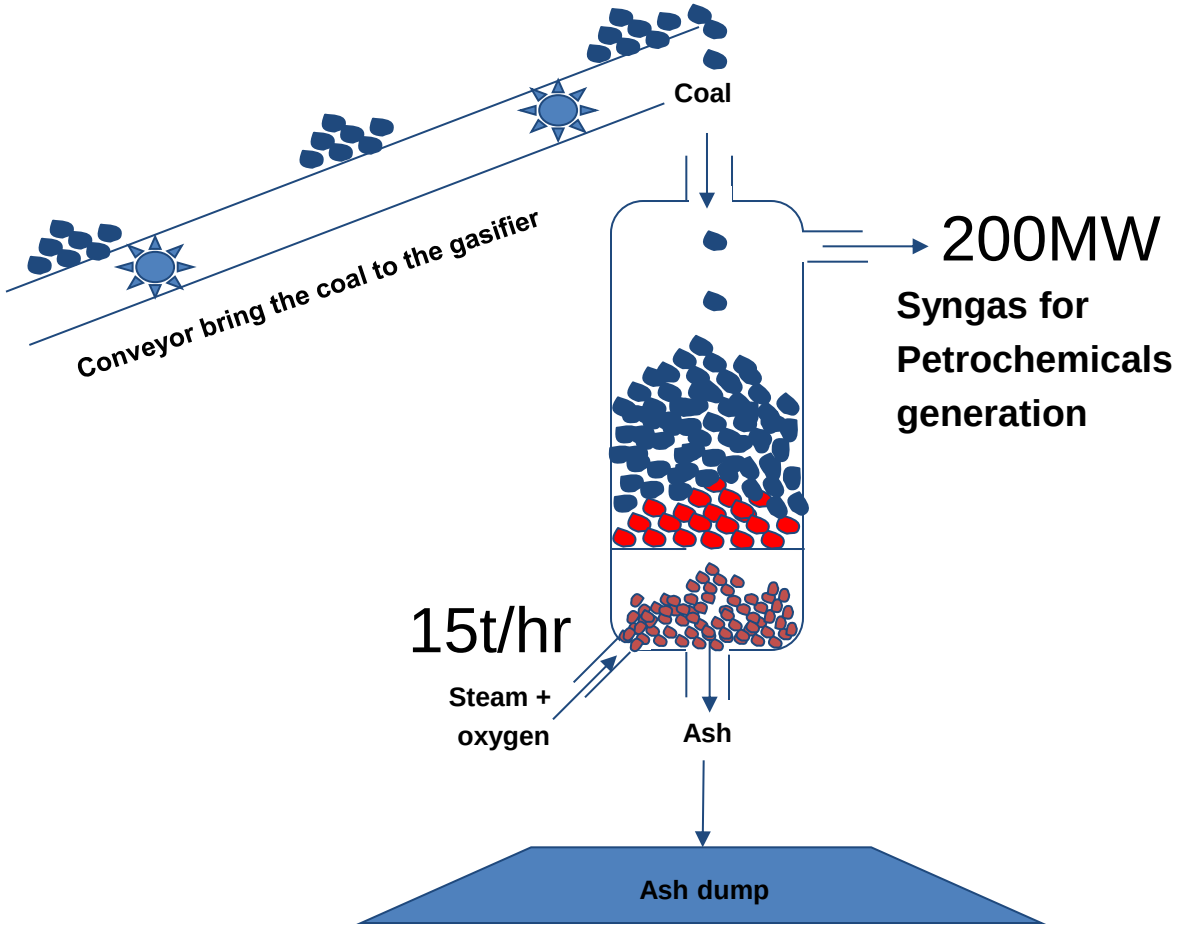


Ignite the coal, Inject O_2 and Extract the syngas

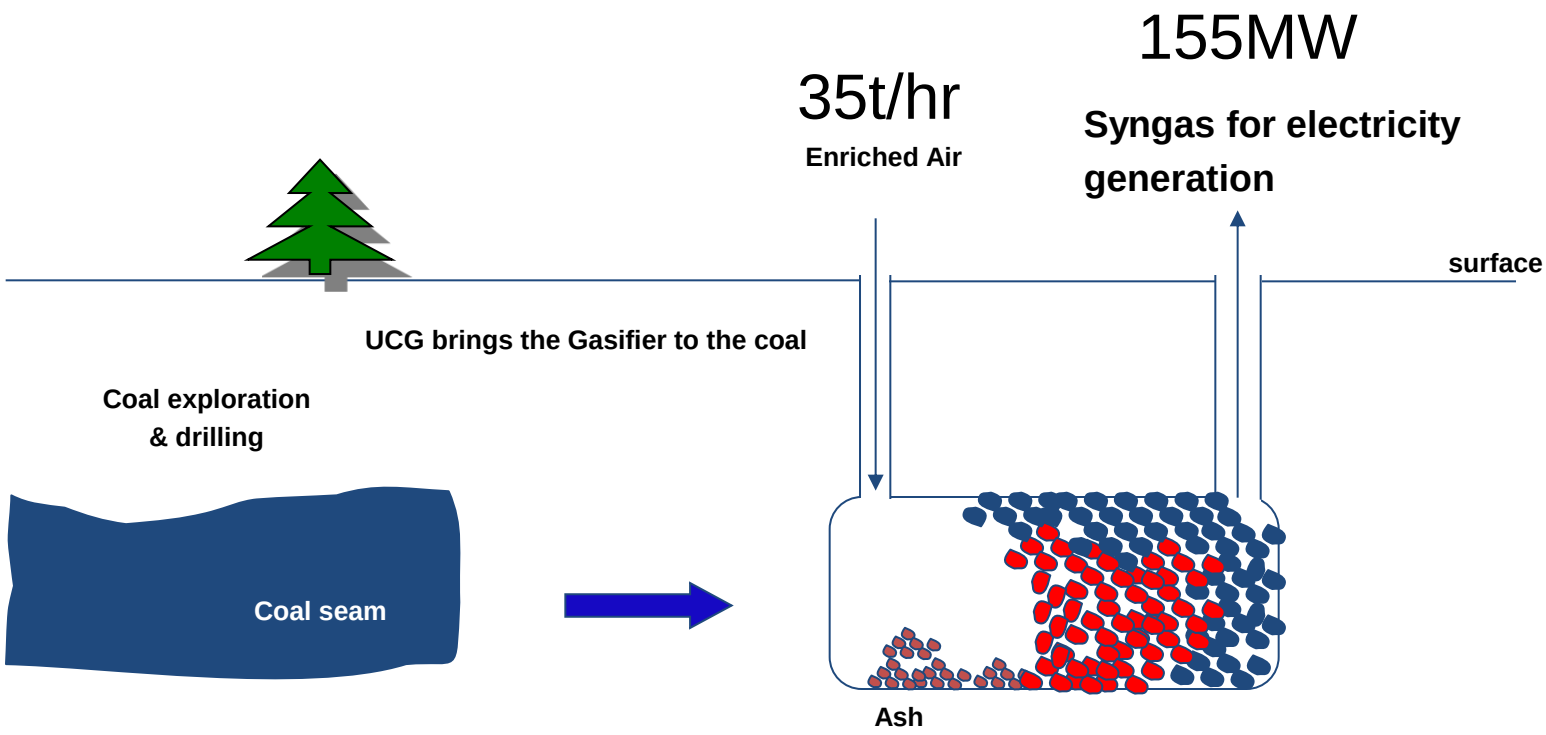


Current Sasol FBDB Gasification





Underground Coal Gasification



Keep the design intent, but move the “Gasifier” underground

Why can UCG play a role in SA ?

- *Coal will remain an important part of the energy mix for decades to come*
  - *Cleaner coal options such as UCG need to be evaluated alongside other energy options*
- *UCG can potentially access coal resources that are not mineable conventionally or not-economical to extract*
  - *Potential to more than double recoverable coal resources*
- *UCG is an in-country energy solution, independent of exchange rate and oil price*
- *SA is at the forefront of UCG development in the world with a number of active projects*

The Dream….of AFRICARY

"To build own and operate a Modern Commercial UCG plant"

and then grow to large scale Poly-generation

- Based on:
- Low cost and abundant resource "**COAL**"
- Growing market demand "**ELECTRICITY**"
  - rising price and 20 year off-take agreement
- Clean, Green and efficient technologies "**UCG**"
  - Use learning and experience from other projects to fast-track and focus

African Carbon Energy ("Africary")

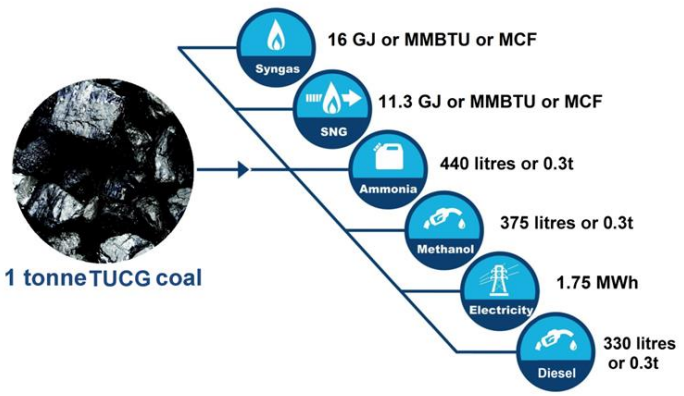
- *African Carbon Energy was established in 2007 as a BEE South African mining and minerals solutions company in order to fulfil the need for a diversified commodities technology supplier in Southern Africa*

- *The company has available expertise in mining, exploration, gasification and specifically Underground Coal Gasification (UCG) and business philosophy is to support equity investments with operational involvement*

- *Africary plans to build, own and operate the first commercial Underground Coal Gasification (UCG) power generation project in South Africa by either winning a Base-Load coal PPA from the recently announced DoE programme or to wheel electricity to prospective clients through the national grid*

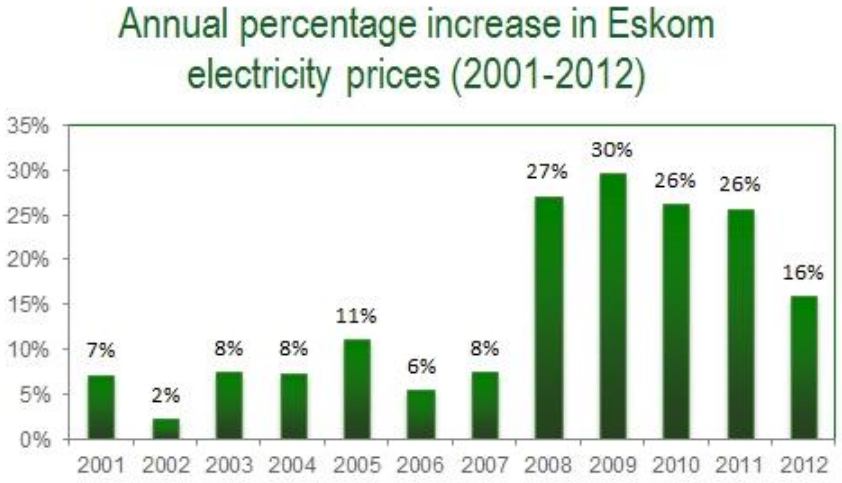
How does UCG Commercialization work?

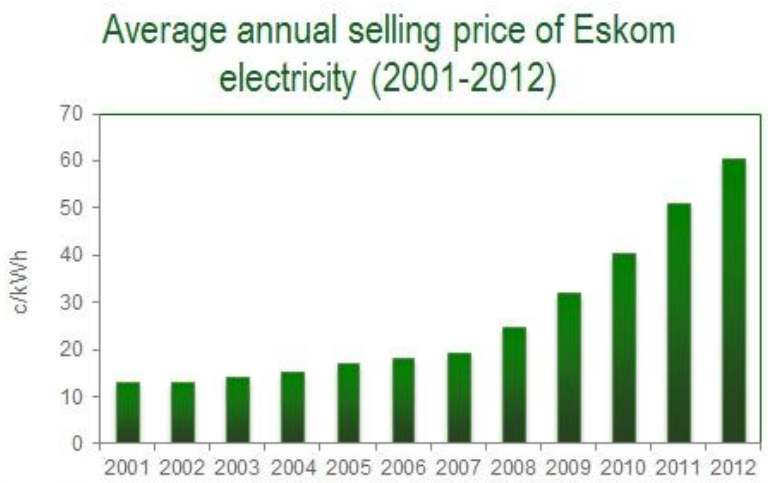
- Step 1: Find a suitable energy Market and do competitor analysis
- Step 2: Obtain a suitable UCG coal Resource
- Step 3: Explore the resource and find and obtain rights to a suitable site
- Step 4: Concept Design finalize Technology choices of the planned facility (PFS)
- Step 5: Risk Assessment and financial suitability assessment
- Step 6: Project Approval / Investment approval
- Step 7: Environmental Applications and permit approvals
- Step 8: Bankable Feasibility Study Engineering Designs with +- 10% Cost Estimate + Marketing study
- Step 9: EPC Negotiations and O&M service level agreements
- Step 10: Offtake Agreement and financial close



Why UCG in SA?

- *With Eskom's 7 years production experience – UCG is a proven SA technology*
- *With increase in tariffs electricity generation by gas engines is cost competitive!*
- *The graph below shows the increase in the average annual selling price of Eskom electricity from 12.98c/kWh in 2001 to 74,26c/kWh in 2013 and is set to continue this trend to accommodate renewable and new built projects (www.eskom.co.za, 18/8/2014)(1US$c = 10.5ZARc)*





URBAN EARTH www.urbanearth.co.za

Source: Eskom 2012

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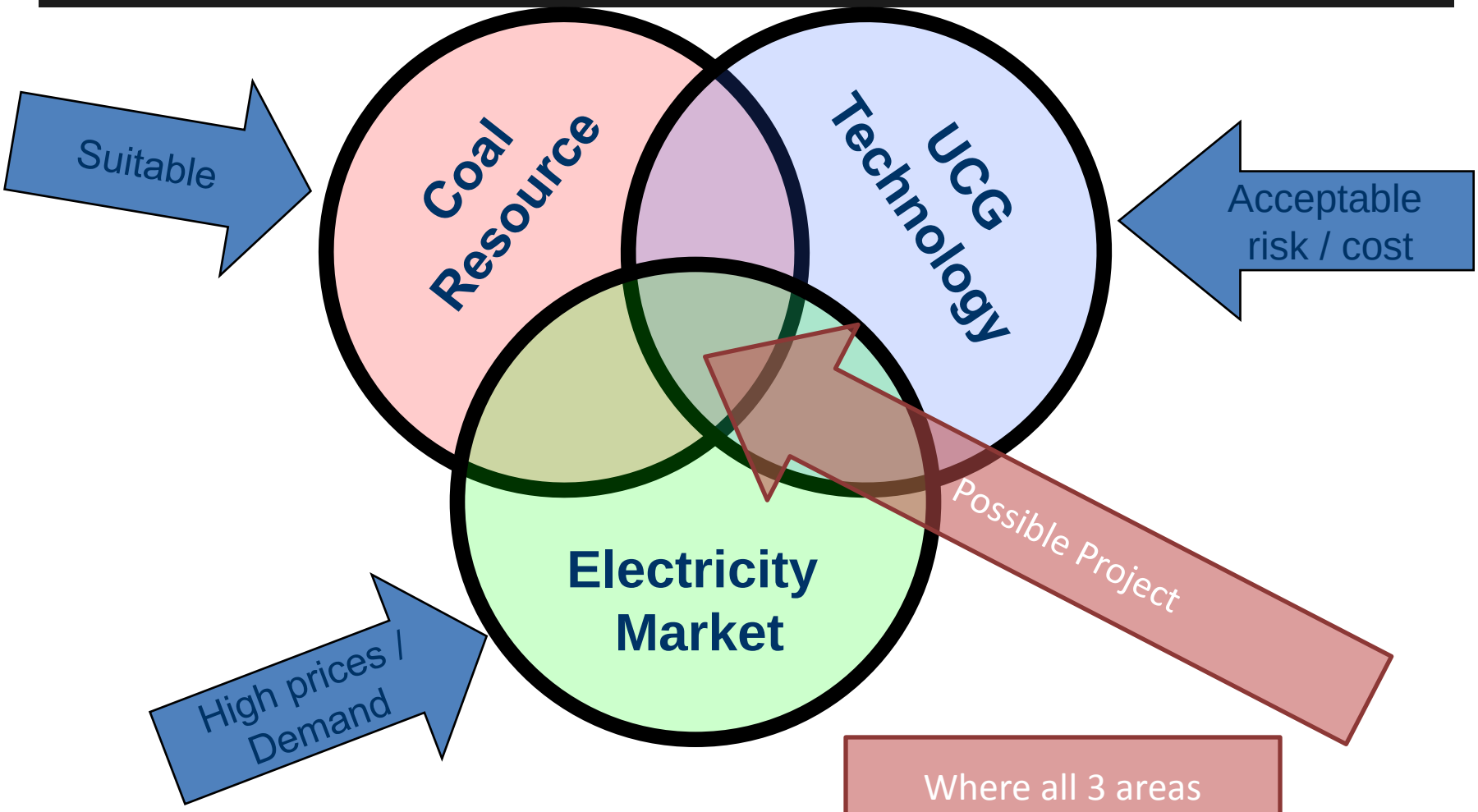
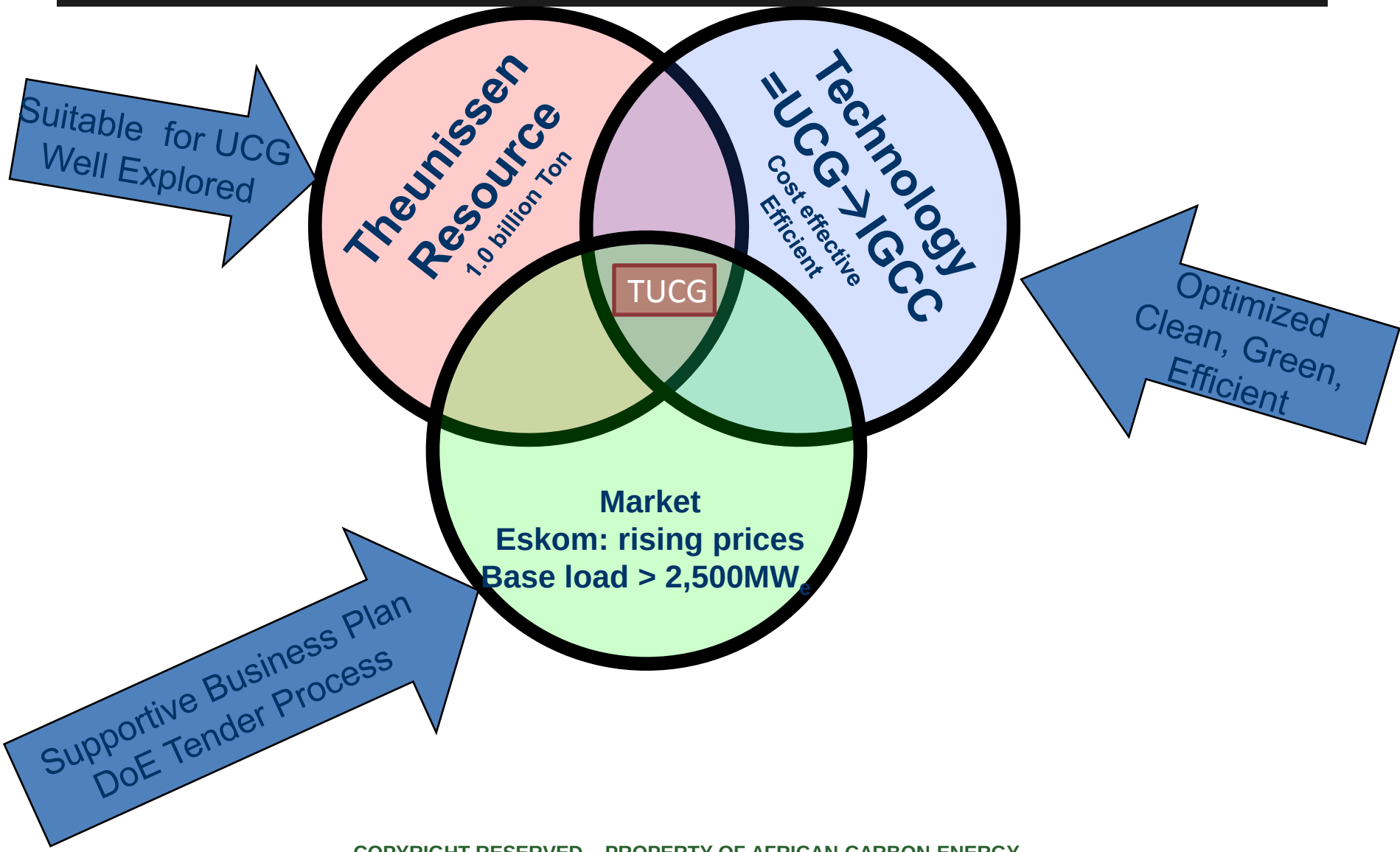
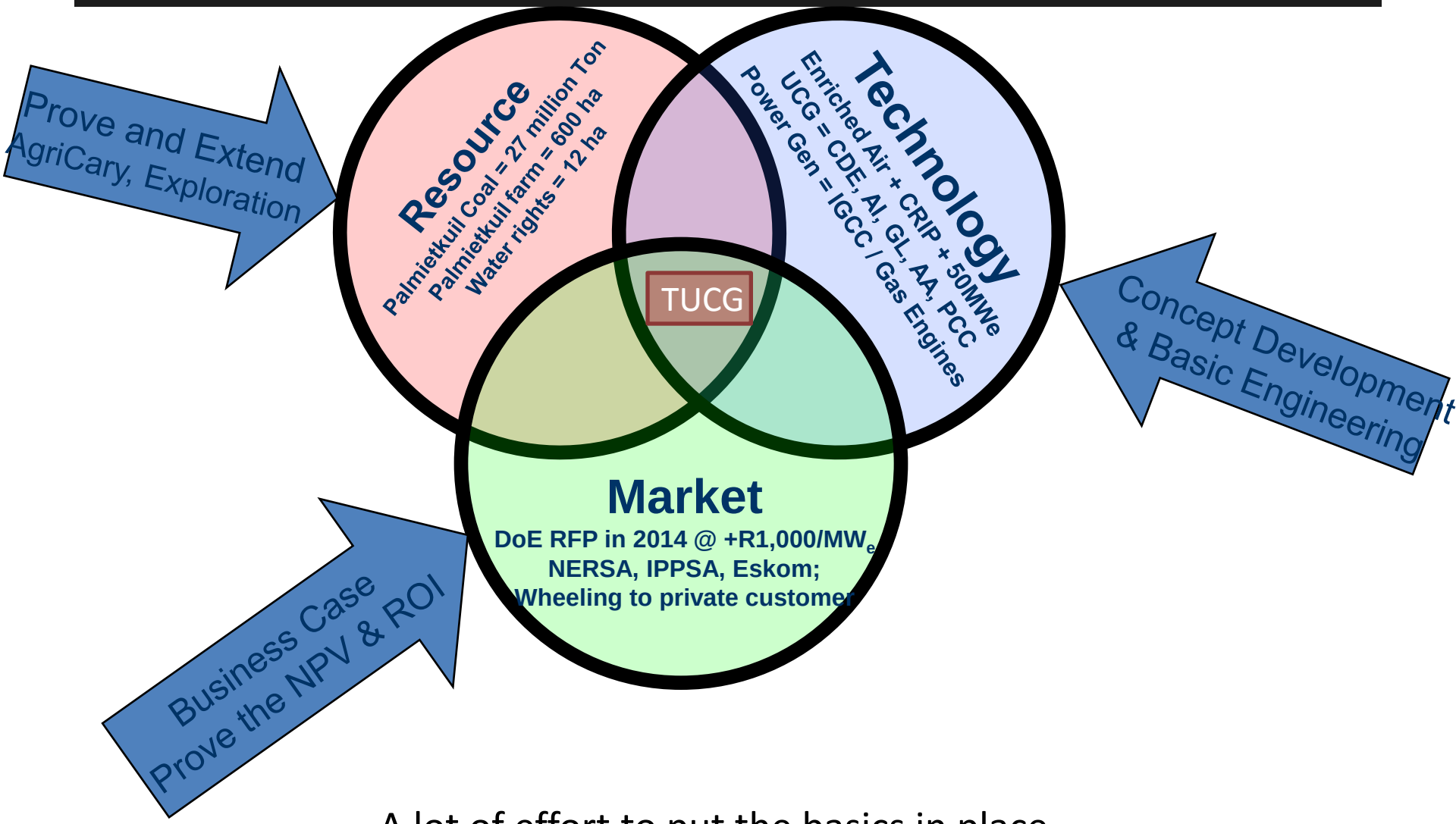
What do I need for UCG Commercialization?



The perfect STORM at TUCG!!!

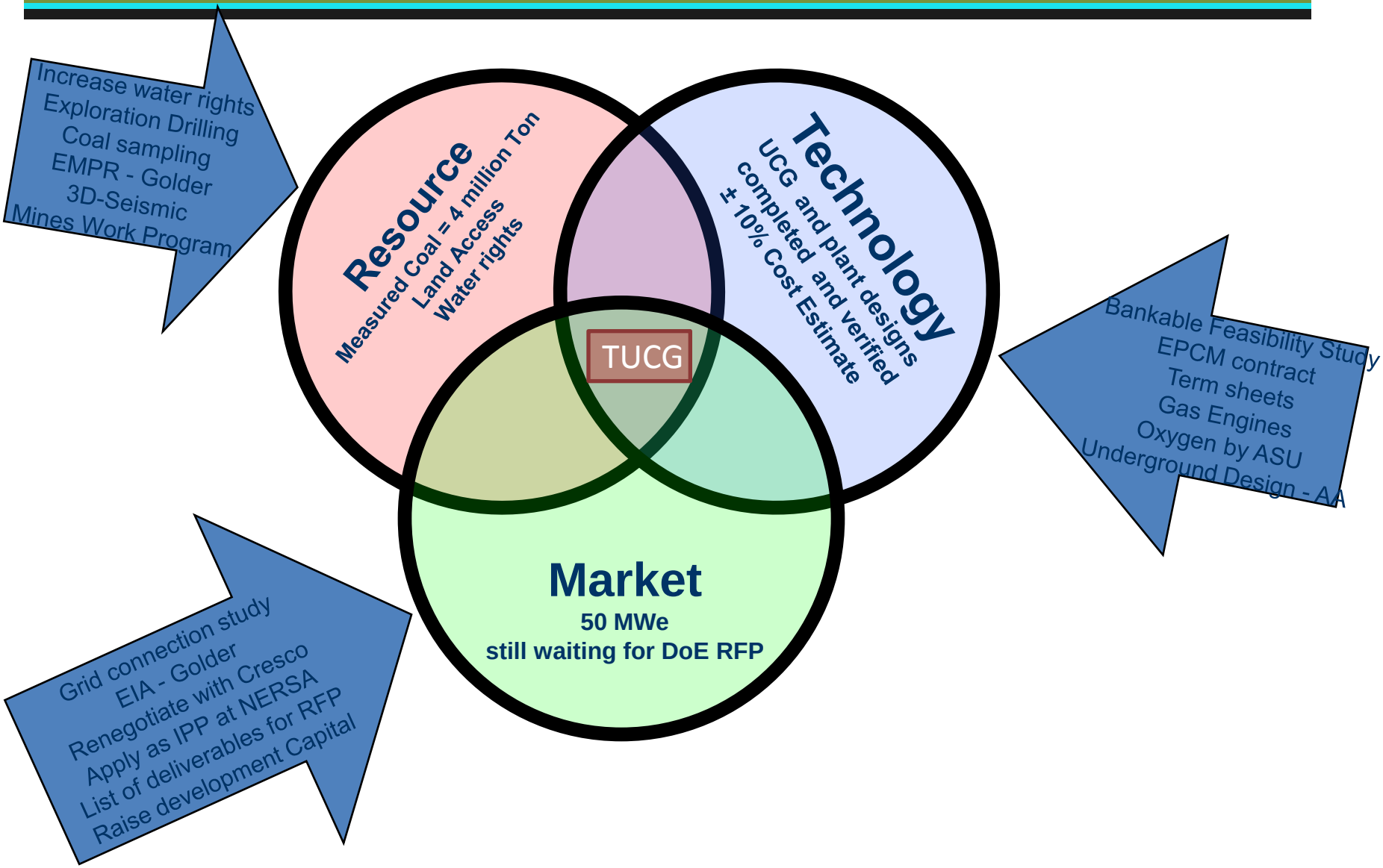


What was completed in 2013/14?



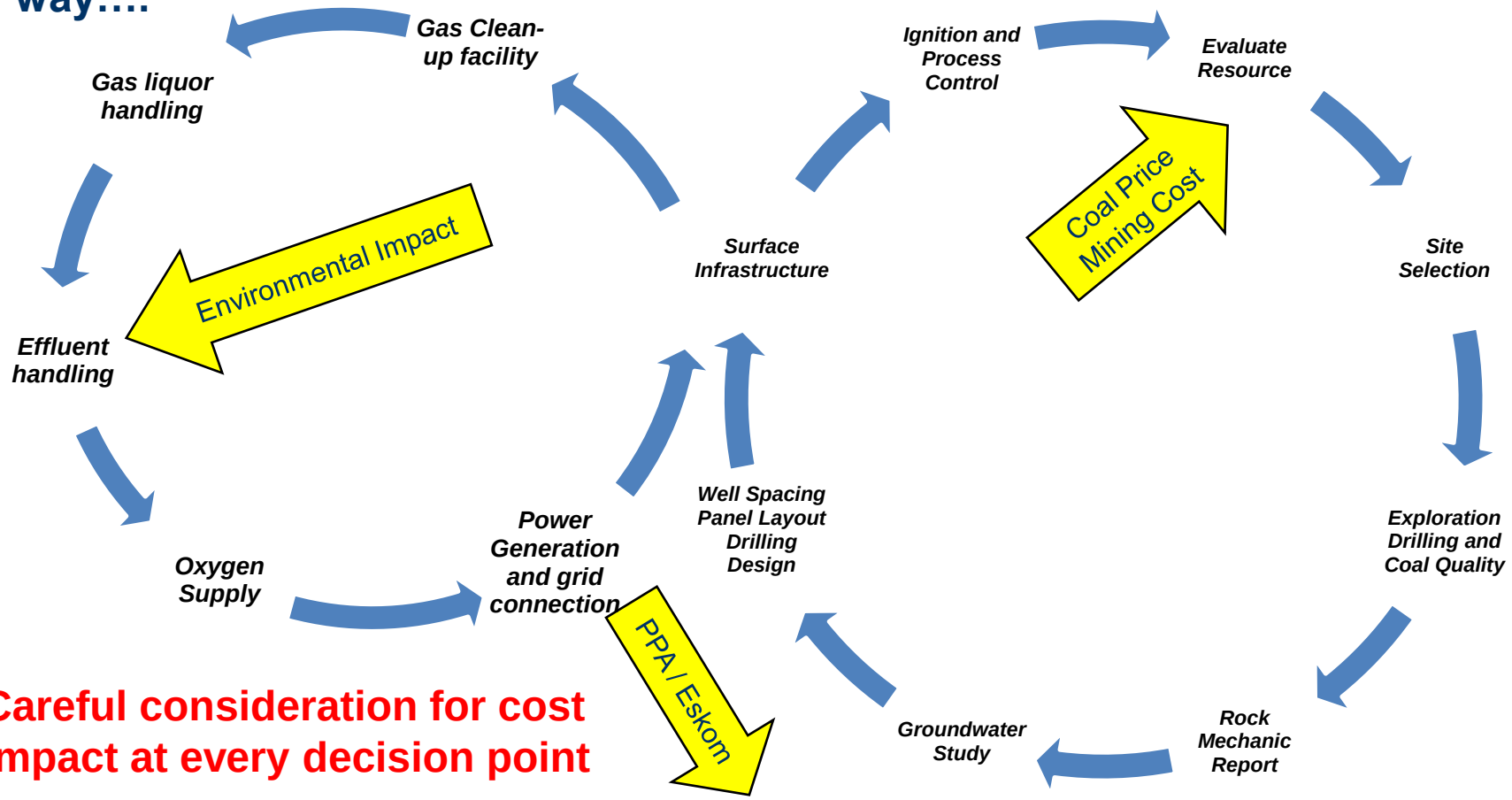
A lot of effort to put the basics in place…

What was completed in 2014?



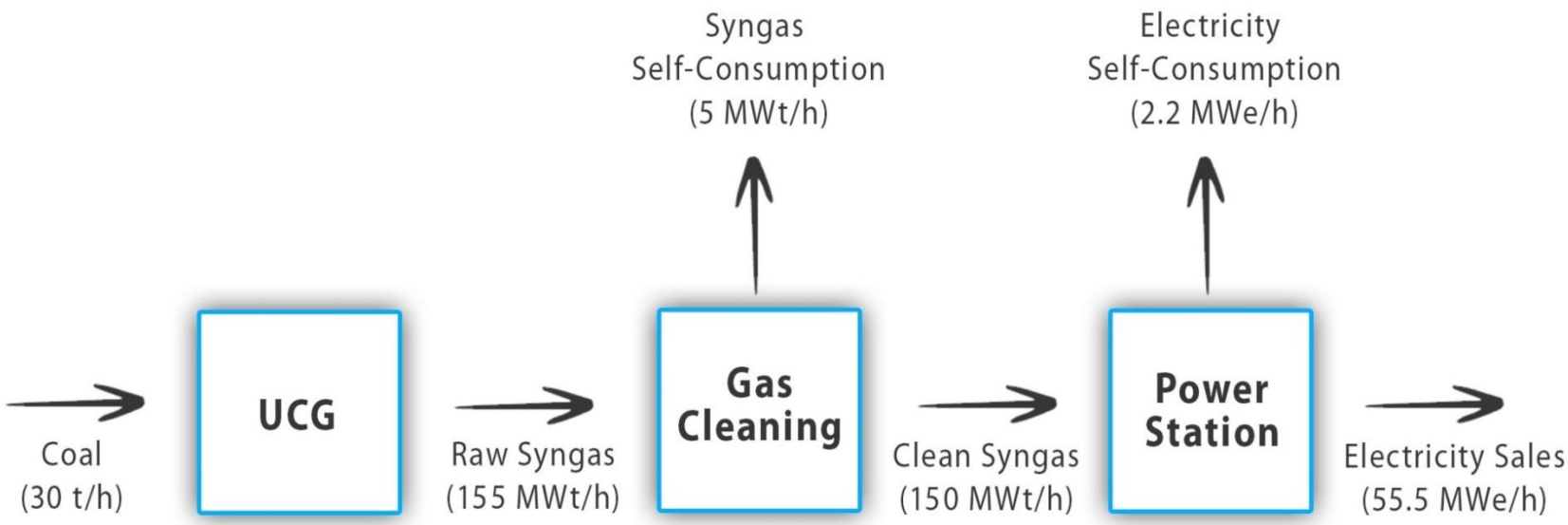
UCG Design Process is dependent on the Resource and Market

an iterative process repeated in more detail in each project phase taking into consideration the Resource constraints, the Market opportunities and the best technology combinations to bring the 2 together in a cost effective / profitable way….



Careful consideration for cost impact at every decision point

Project basic mass and energy balance: Simple enough, but complex integration



Coal to Gas:
Energy conversion is
80% efficient

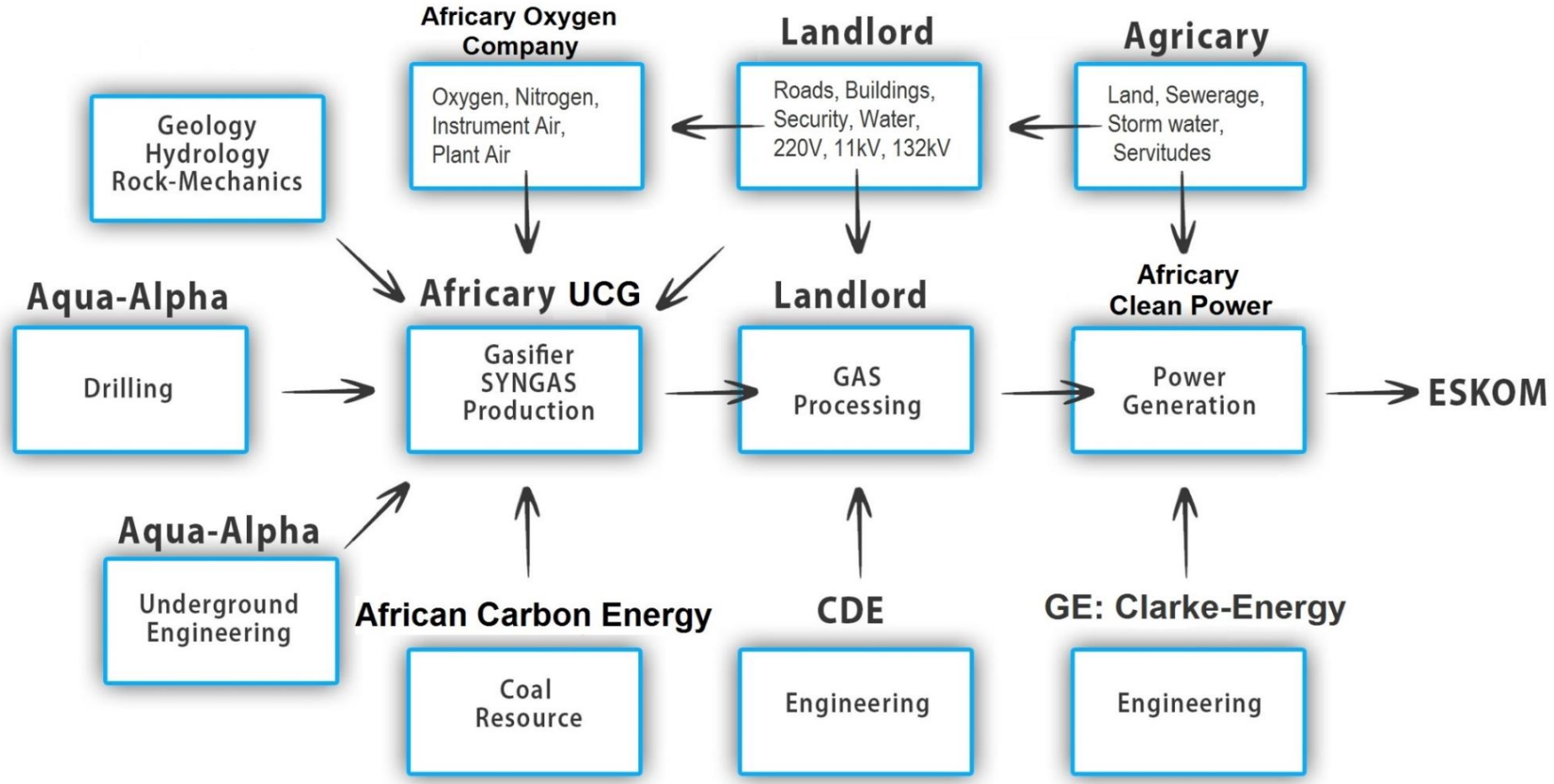
Gas to Electricity:
Energy conversion is
38% efficient

Commercialization requires several disciplines and vendors to work together

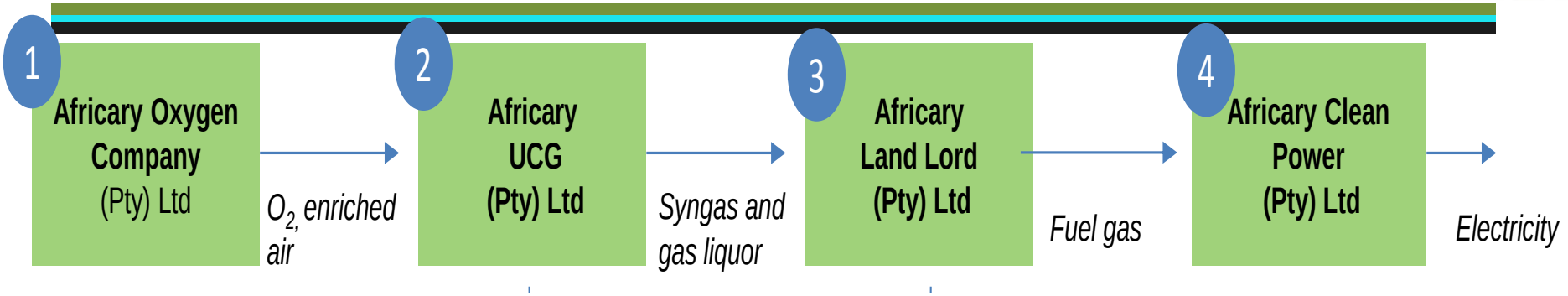
	(a) Oxygen Supply	(b) Resource	(c) UCG Technology	(d) Gas Processing	(e) Power Generation
Required Expertise:	• Construction and operation of oxygen plants	• Ability to evaluate coal resources and their suitability to UCG technology	• Drilling, • Coring, sampling • Gasifier design • Geology, • Hydrology	Gas processing expertise: • Gas cooling, • Gas clean up • Sulphur recovery	• Construction and operation of power plants (run on syngas)
Africary's Approach:	• Will seek third party involvement	• Acquired coal rights from BHP Billiton with an inferred status of 1 billion tons.	• Established a team of [15] in-house experts. • Established strategic partnerships with CDE and Aqua Alpha.	• Use Sasol based CDE	• Will seek third party involvement

Africary's coal competencies *lie within the UCG mining aspect of the value chain. As such, Africary seeks to use its expertise to harness the energy from Theunissen coal deposit with UCG technology, enabling the company to become a low cost fuel provider for power generation or poly generation of chemicals.*

Project supply chain – Major Vendors play a crucial role in cost management



Company structure (4 SPV's is utilised to manage the legal and commercial structures)



The production of enriched air, which shall be fed into the UCG process for the production of syngas.

The entity is responsible for the supply of the oxygen component at pre-agreed conditions and purity, as well as other required and related gaseous process streams to Africary UCG.

Its major asset will be a cryogenic air separation unit that will most probably be operated and maintained by an independent contractor.

The production of syngas and gas liquor from the UCG mining activities.

Africary UCG purchases oxygen from Africary Oxygen Company, which is used to mine and gasify the coal to produce raw syngas (syngas and gas liquor).

Its major asset will be the UCG mining and gasification facility, gas cooling, flaring and venting system. These units will be operated and maintained by Africary.

Produce clean Fuelgas by buying syngas from the UCG mining company and processing the gas into an environmentally clean fuel gas that will be sold to Africary Clean Power for power generation

Act as the landlord and provided for all the facilities to be able to operate independently in a remote location (distribution networks, aqueous utilities, safety systems, fire protection , effluent treatment, workshops, offices, laboratory, roads, security, etc.).

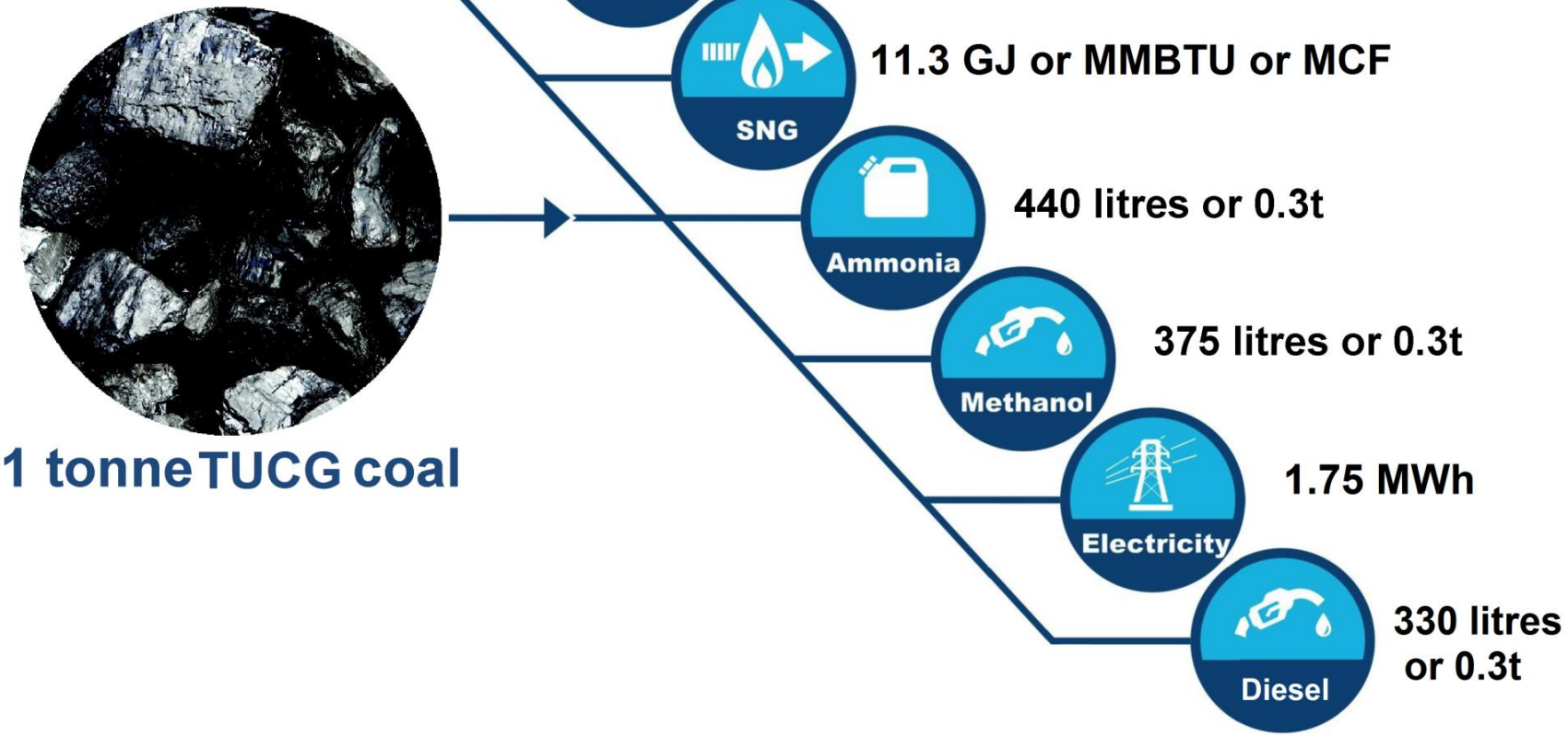
an IPP company, which shall produce electricity from the fuel gas bought from the Africary LandLord.

The produced electricity shall be sold off to Eskom via a Power Purchase Agreement (PPA).

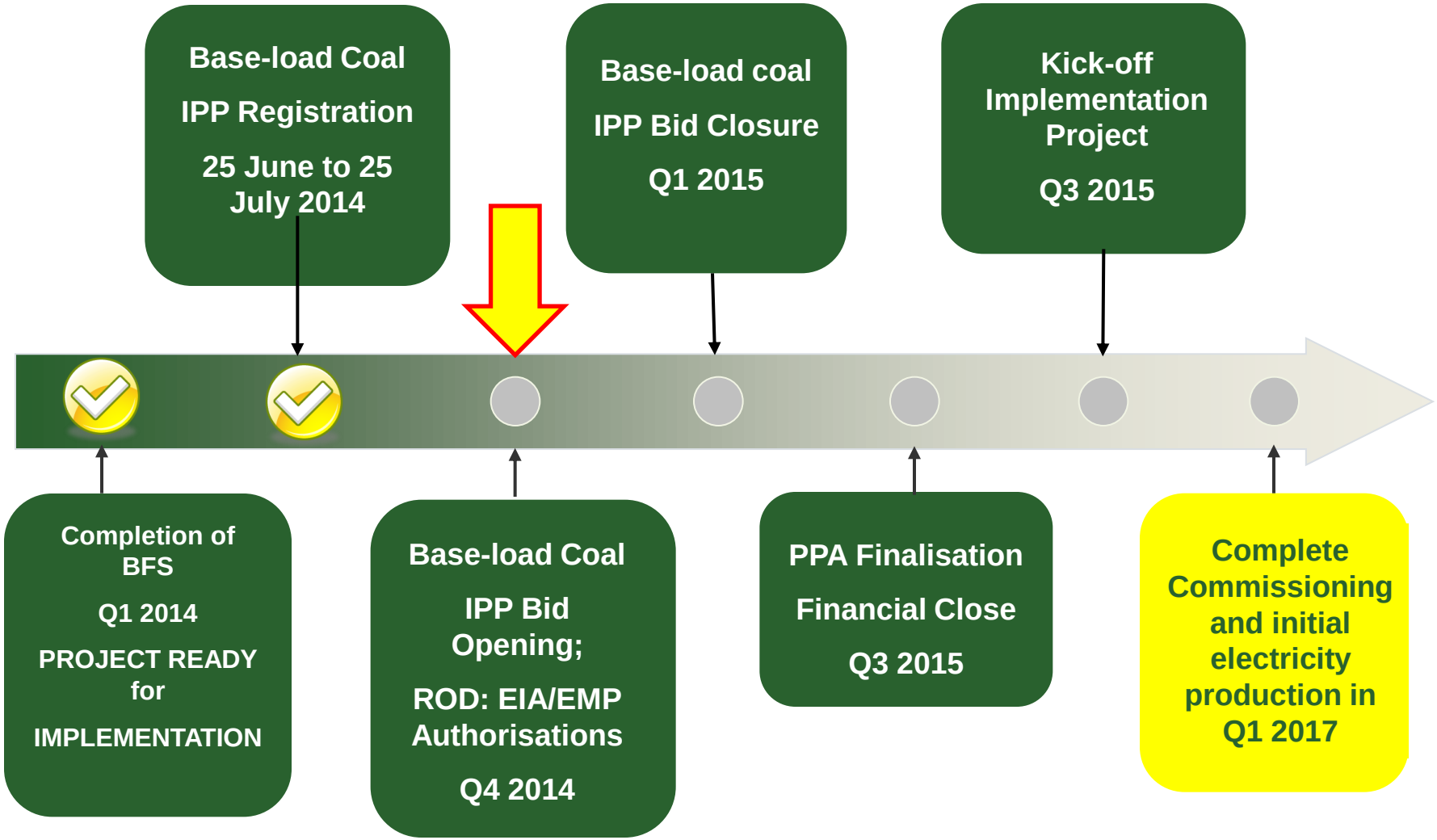
The IPP will tender for the supply of more than 50MWe to Eskom

Its major asset will be 60MW installed capacity GE Gas Engines

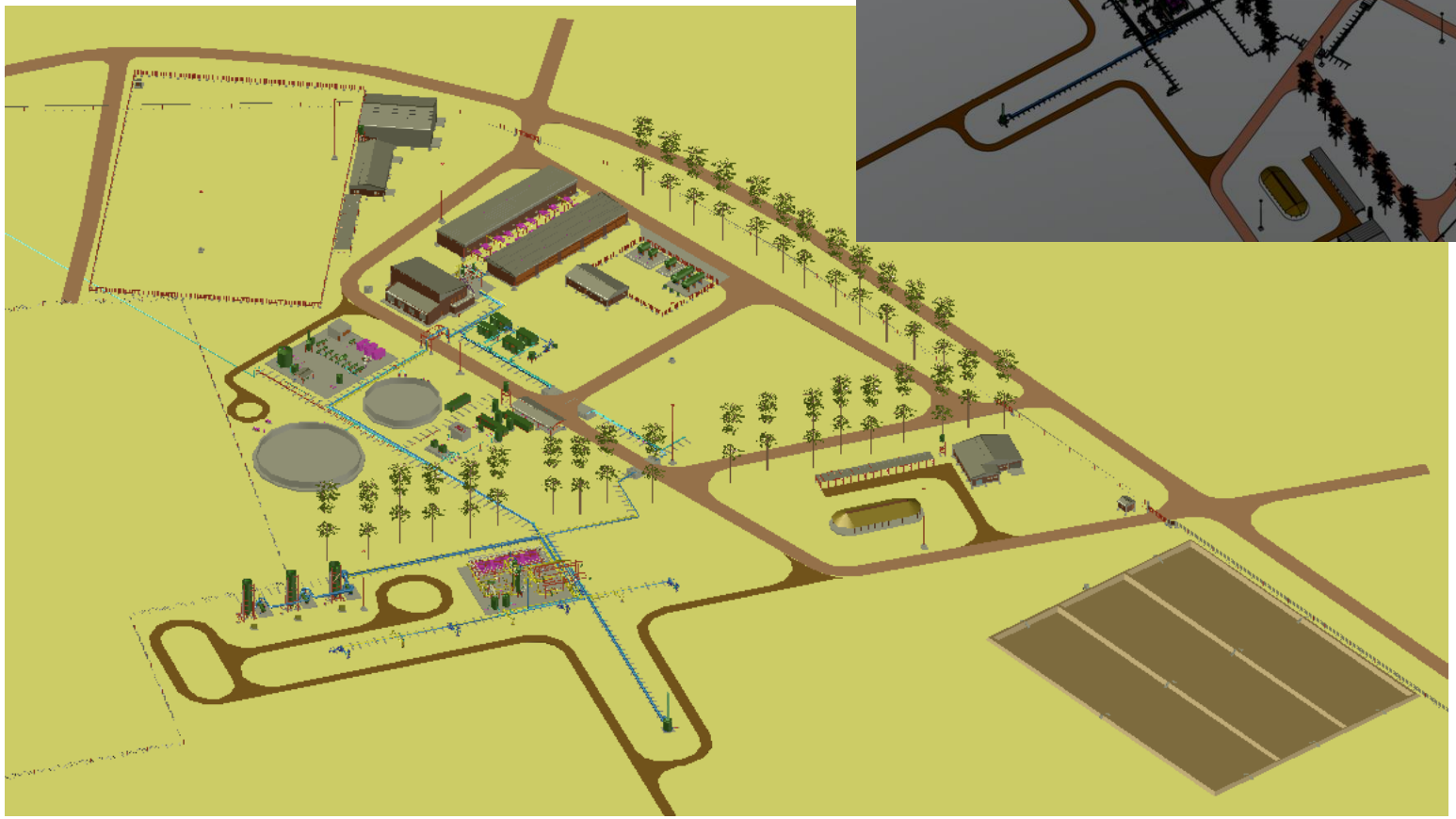
Coal to Syngas has many paths to market



Key Project Milestones

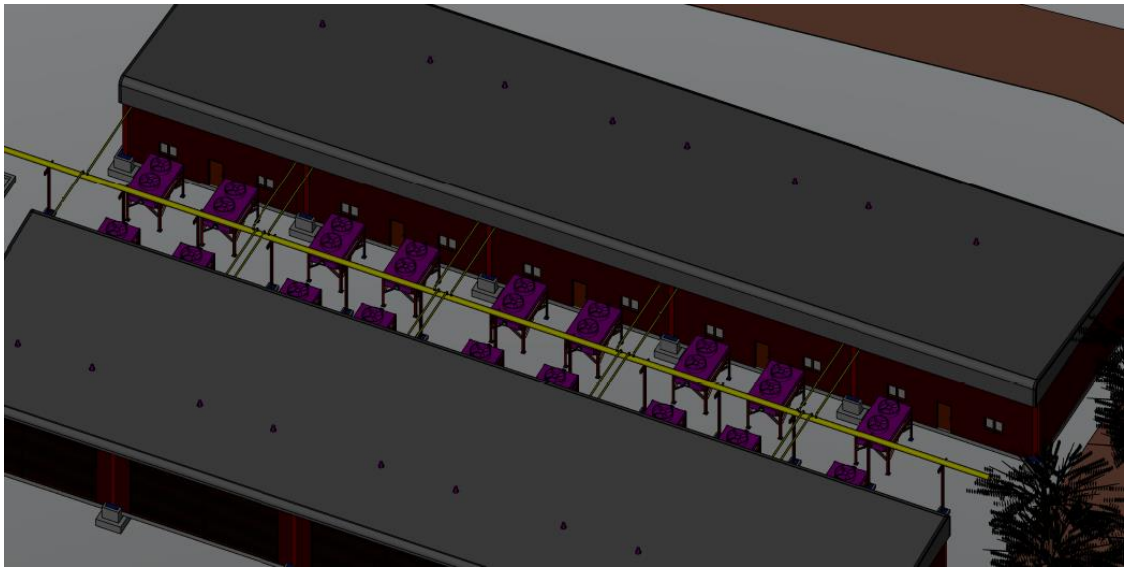


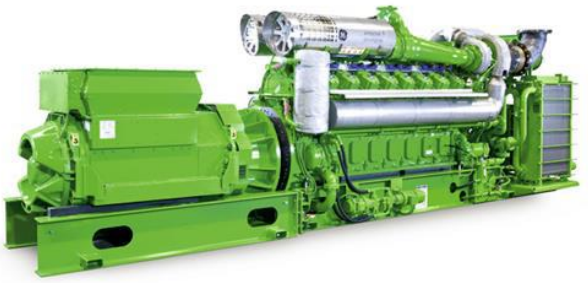
Areal overview of plant



Plant sub-buildings

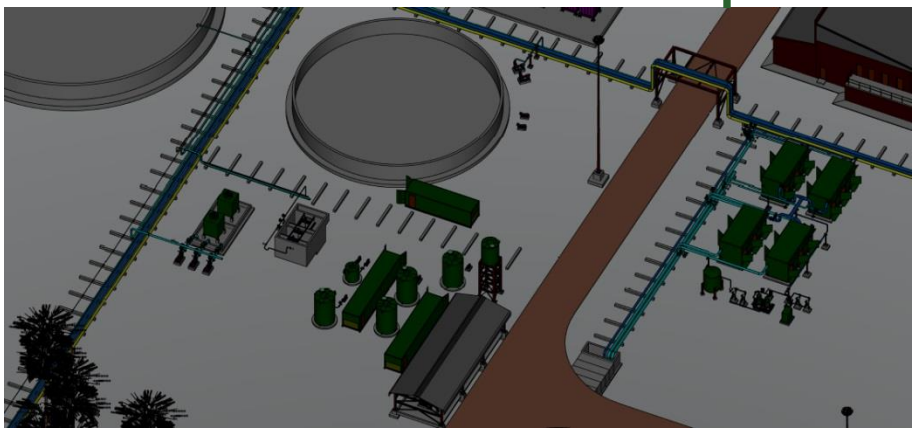
Engine buildings



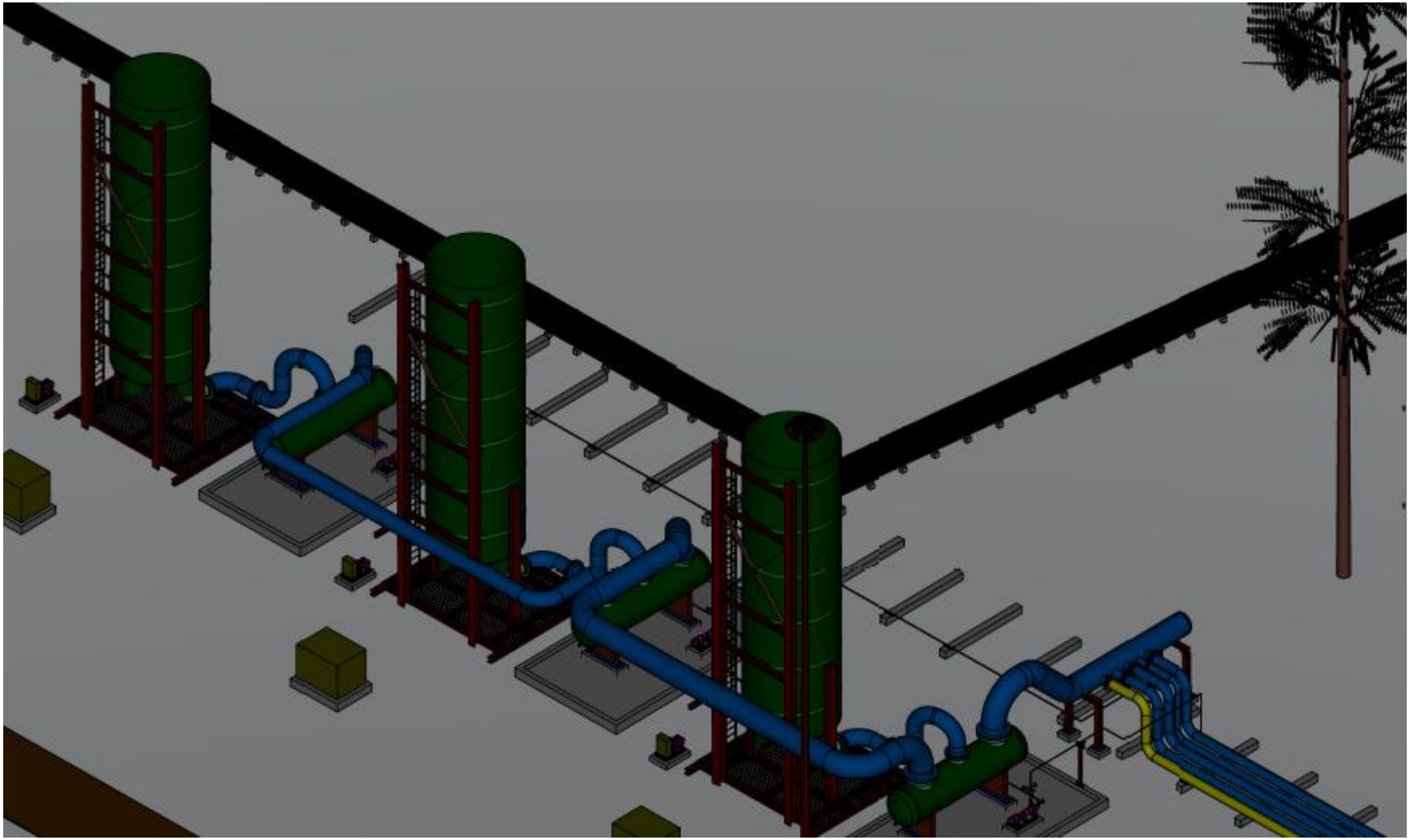


30 x GE-Jenbacher Gas Engines to operate on Syngas

Waste treatment and air compression

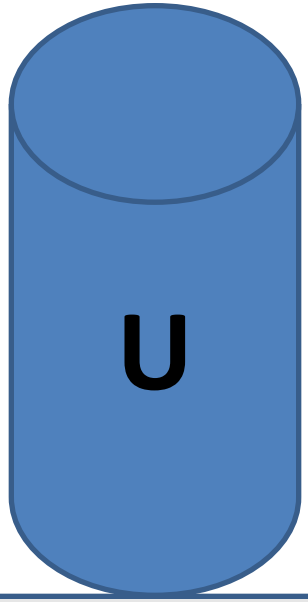


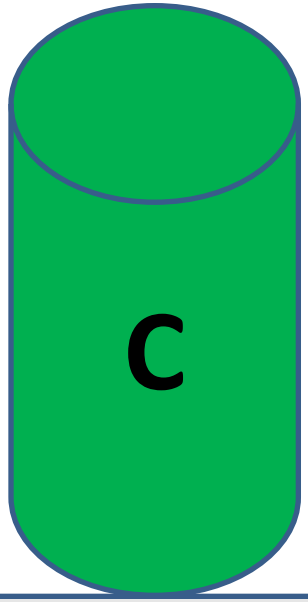
Flare system

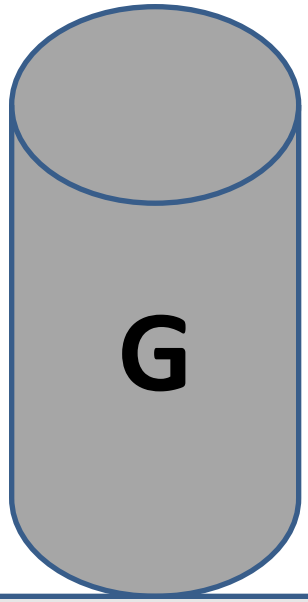


Solid foundation and support for TUCG from many companies

AFRICARY







AQUA ALPHA
"Directional Drilling Solutions"

ATS
AQUATRONIC SOLUTIONS

Geoline Services
Wireline Logging

BUREAU VERITAS 1828
INSPECTORATE

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Malatleng Mining cc

rock & stock
INVESTMENTS

A&B MYLEC PTY LTD
INNOVATIVE SOLUTIONS
METALLURGICAL CONSULTANTS

Stable
ΣΣX
Strata
Consulting

AFRICARY

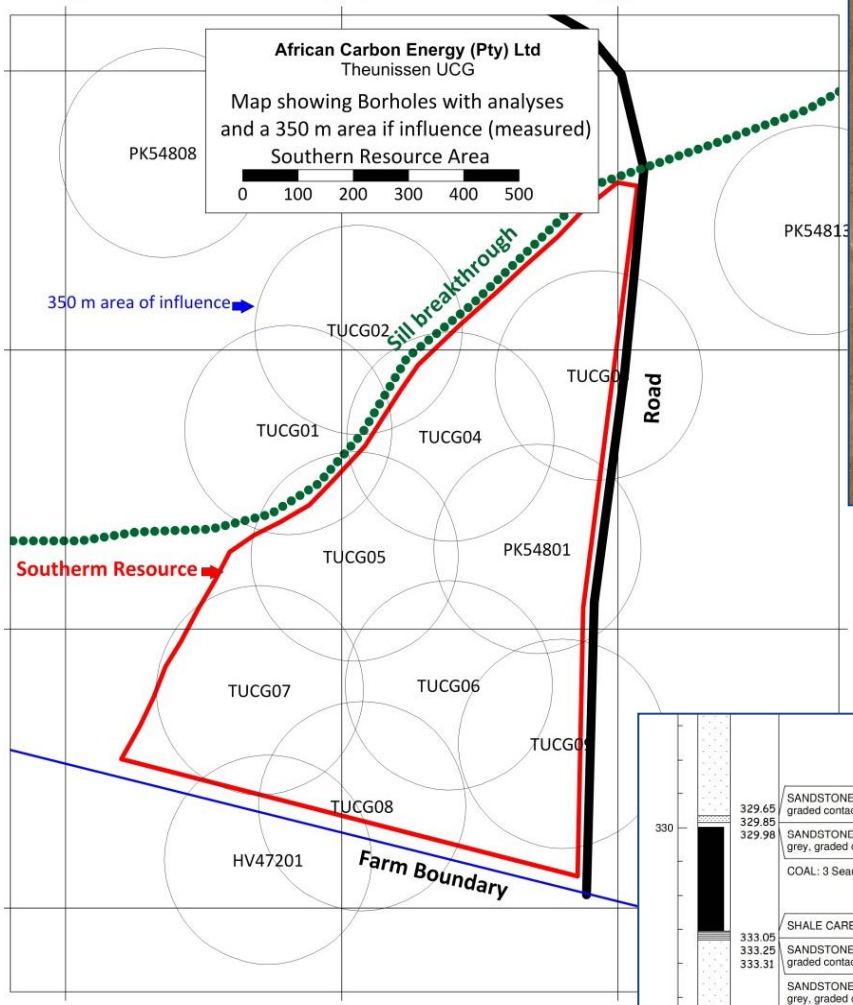
Golder Associates

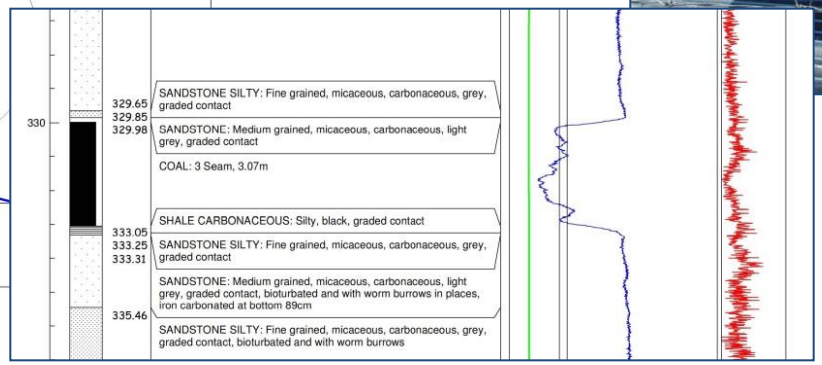
MacRobert
Attorneys

CDE Process
beyond engineering

P.D.I DRILLING
DRILLING CONTRACTORS

“Coalology”: Proven coal supply!





“Coalology” Properties of the coal

ANALYSES	PURPOSE
Proximate analysis: Moisture, Volatile matter, Ash, Fixed Carbon*	Mass balance, ash content, water
Total Sulphur*	Environmental, gas cleaning design
Gross Calorific Value*	Efficiency of process
True relative density	Mass balance on coal, measured resource classification
Ultimate: C, H, N & O (by difference)	Mass balance, oxygen consumption, gas quality
Forms of sulphur: Pyritic, Sulphate & Organic	Speciation, environmental, gas cleaning
AFT (oxidizing conditions)	Gasifier operating window
Ash composition: SiO_2, Al_2O_3, Fe_2O_3, TiO_2, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3	Influence acid/base ratio of ash, slagging, trace element capturing
Fischer Assay: Char, Liquid hydrocarbons, Water, Gas (by difference)	Liquid hydro carbon yields, tar and oil
Petrographics: Maserals and rank (COAL DEFINITION)	Reactivity, coal classification, tar yields, and much more
Mineral composition	Type of minerals and not composition, i.e. clay, sulfates, carbonates
Trace elements analyses	Environmental, gas cleaning design
Chlorine, Cl	Environmental, gas cleaning design, corrosion
Fluorine, F	Environmental, gas cleaning design, corrosion
Crucible swelling number	If coal is caking coal / plasticity
Gieseler fluidity	If coal is caking coal / plasticity
Self-heating and Spontaneous Combustion	Rate of combustion, start-up
Pore size and surface area	Reactivity, cavity formation, gas velocity expected

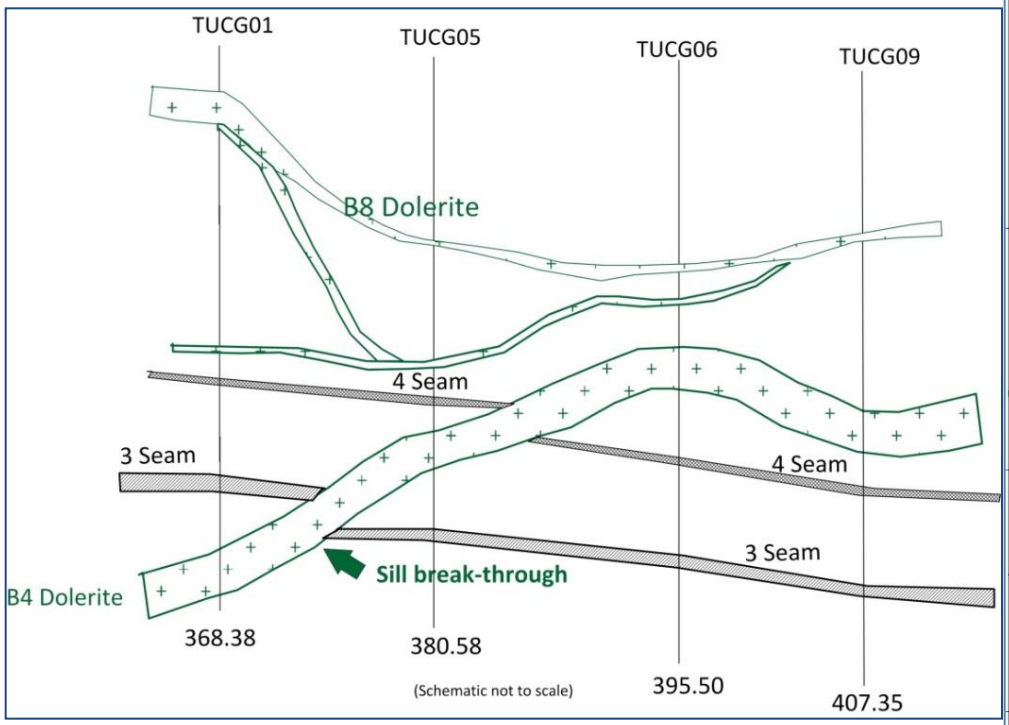
MEASURED RESOURCE

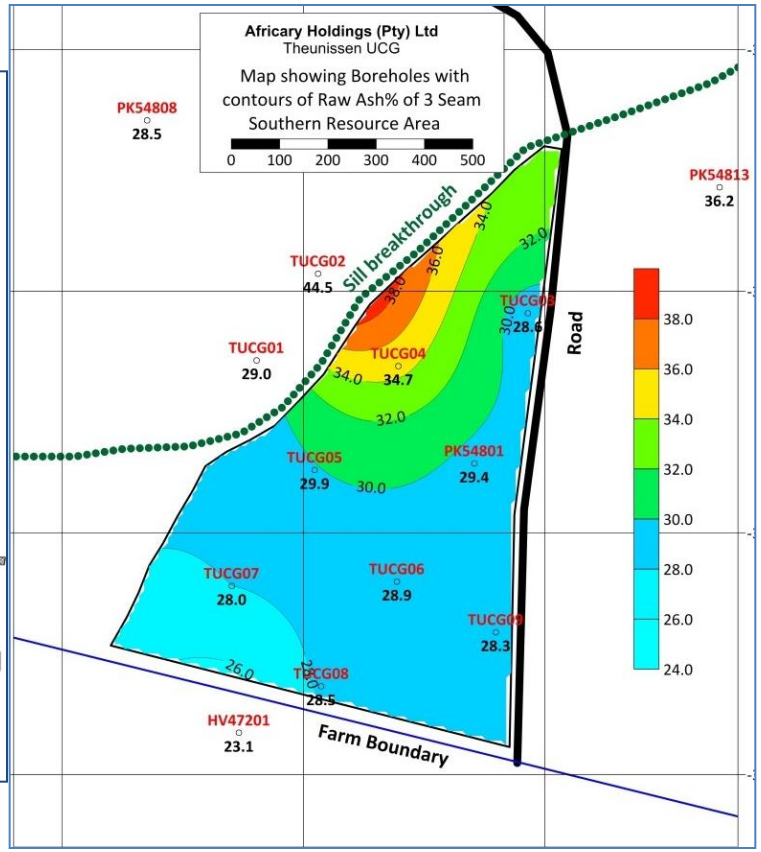
ENVIRONMENTAL + *

MASS AND ENERGY BALANCES + *

GASIFIABILITY AND RATE OF GASIFICATION

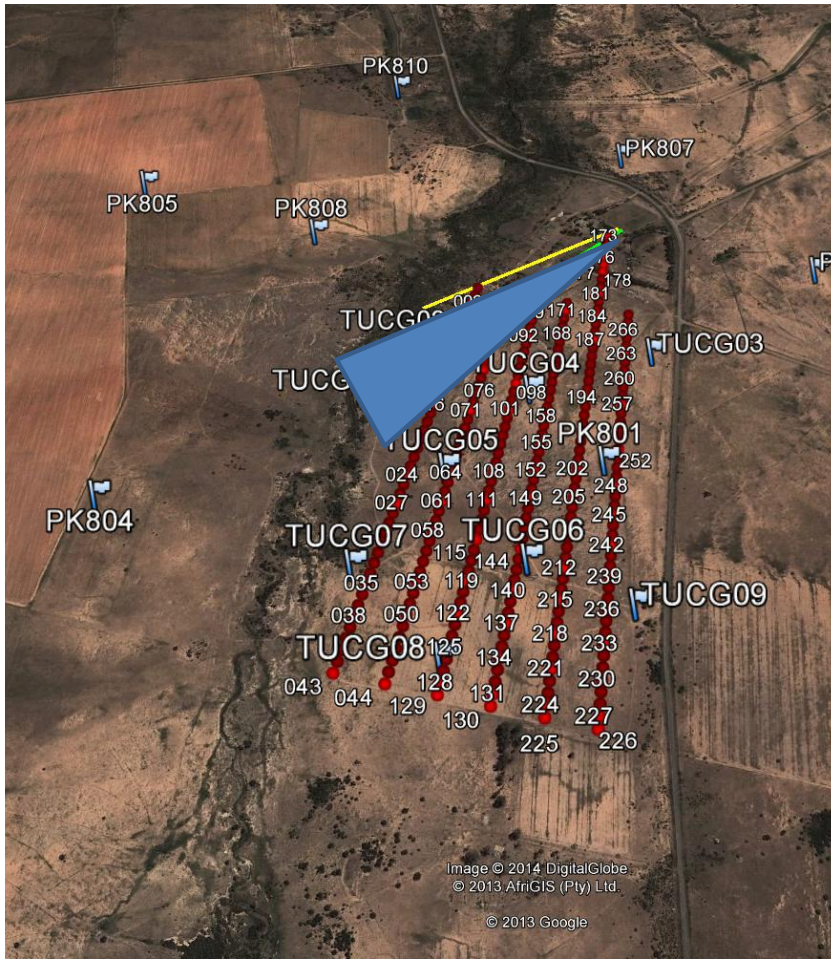
C "Coalology": Geology and formation





Statistic	Moisture%	Ash%	Volatiles%	daf VM%	Fixed Carbon%	Sulphur%	CV(MJ/Kg)	Yield%	Raw RD(g/cc)
Wgt Ave	4.26	30.81	19.18	26.41	44.25	0.66	20.31	100.00	1.62
Max	7.30	50.10	26.80	39.00	59.66	1.96	24.32	100.00	1.86
Min	2.31	20.04	4.40	8.01	20.34	0.28	15.04	100.00	1.46

“Coalology” Electro-seismic study



1) Two shallow aquifer systems at 20m and 40m.
2) A 270m thick sandstone between the upper aquifers and the coal seams.
3) Geological horizons interpreted by the ES analysis are consistent with the well logs completed.
4) Possible vertical dyke formation to the North West of the site that may be intersecting the coal seams.
5) Indications of shallow dolerite sills close to the surface.
6) The water quality within the upper aquifer systems varies only slightly, indicating that they are connected and/or sourced from the same feed source.
7) Negligible communication within the upper sandstone formation and the Vryheid coal seam formation - indicates low permeability.
8) The upper and lower coal seam have very low hydraulic conductivity values ranging between 0.01 and 0.001 cm/day.

AQUATRONIC SOLUTIONS *Developers of Geophysical Equipment and Software*

Dr. Michael Du Preez

“Coalology” Geophysical study

Not to Scale!
(Otherwise you will not be able to see what is happening…)

		ADVANCE		
		100m	100-300m	>300m
Cavity Width	0-100m	Only local collapse	Only local collapse	Only local collapse
	100-300m	Only local collapse	30-100m collapse	30-100m collapse
	>300m	Only local collapse	30-100m collapse	Full collapse

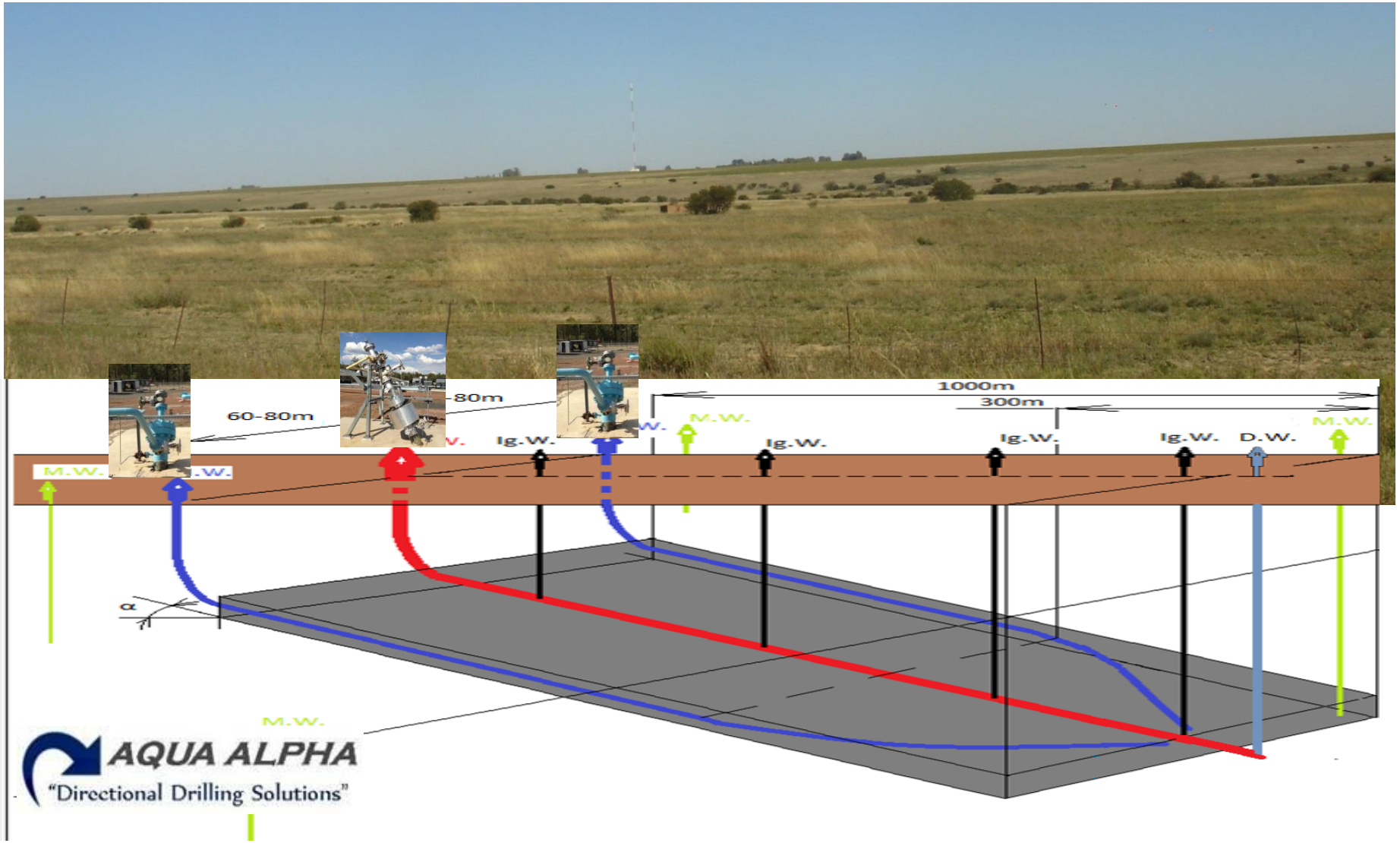
Stable
ΣΣX
Strata
Consulting

Underground technology and getting into the coal seam

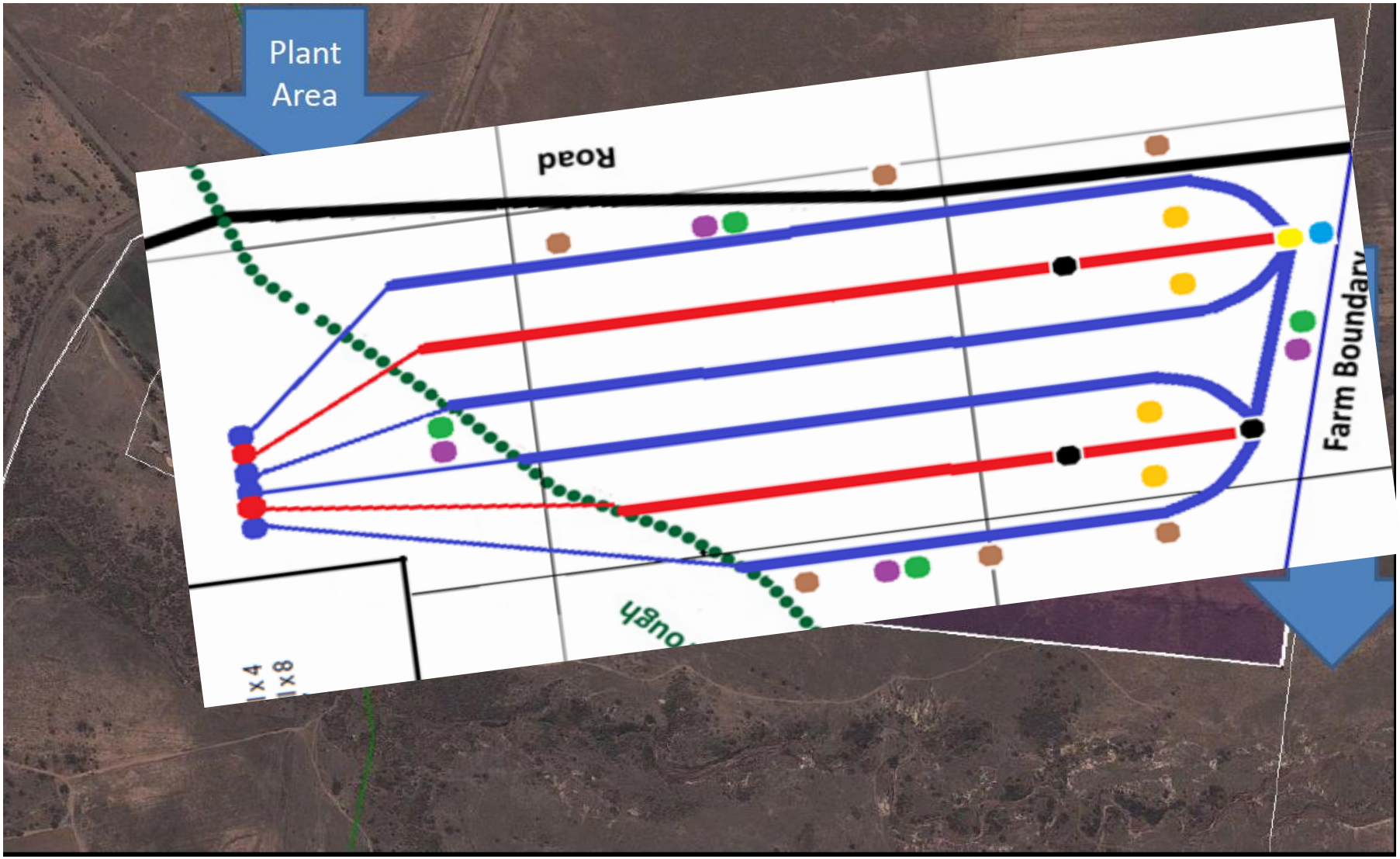
Aqua Alpha consist of ex-Sasol Directional Drilling team

- 20 years directional drilling experience
- Adapted oil industry directional drilling technology for use in coal exploration
- Developed specialized drilling rigs for coal exploration with directional drilling
- Awarded by the South African Institution of Mechanical Engineering
- Record drilling of more than 1,000,000 metres of directional wells in coal seams
- Achieved several world firsts in directional drilling:
  - *2 164 metre long horizontal well drilled inside a coal seam from surface*
  - *1 529 metre long horizontal well drilled inside a coal seam from underground*
- In conjunction with Africary AA has designed the TUCG continuous injection point retraction (CRIP) systems for underground coal gasification

Underground technology and getting into the coal seam



Underground technology
Directional Drilling into the coal seam

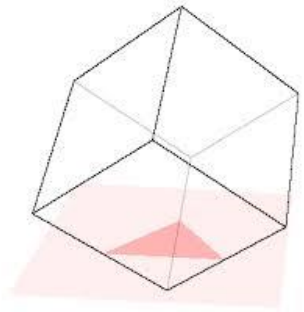


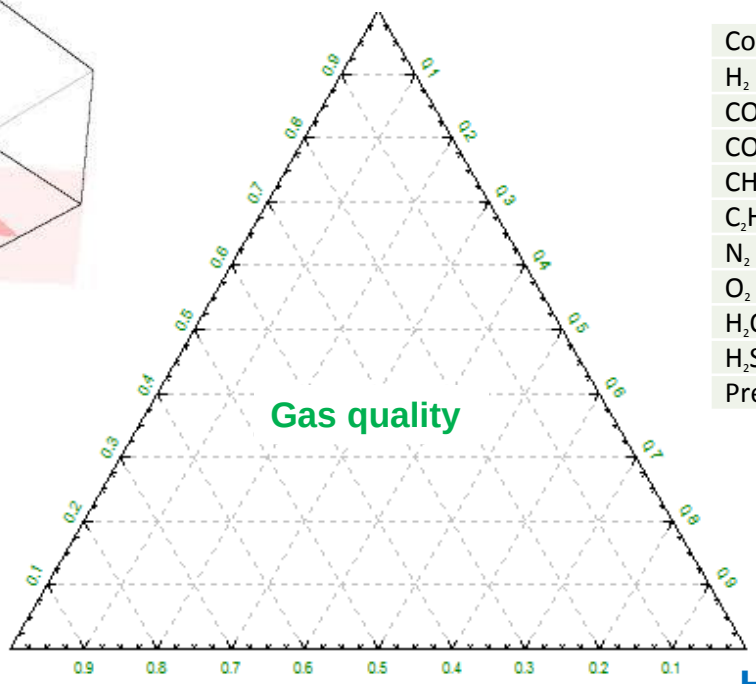
Gasification science - Experience

- >40 years coal conversion experience within Africary
  - *Dr JC van Dyk*
  - *Mr JF Brand*
- Mr D du Preez and team (decades of engineering and gas processing experience)
- NWU – Proff Waanders, Neomagus, Strydom and Dennis

Gasification science – a 4D+ space

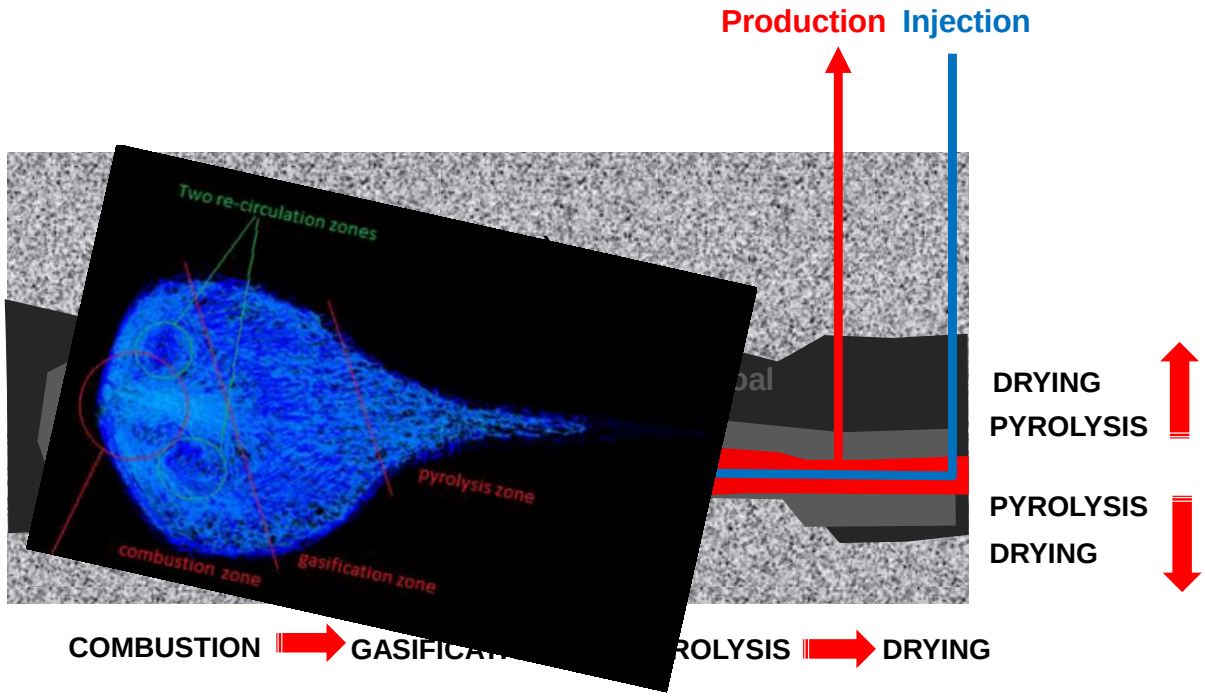
EFFECT OF PRESSURE, WATER CONTENT AND AIR:O_2 RATIO ON GAS COMPOSITION





Component / Property	Units	Normal (%)
H_2	mol %	8-12
CO	mol %	16-24
CO_2	mol %	18-25
CH_4	mol %	8-12
C_2H_{4-6}	mol %	<1
N_2	mol %	30-40
O_2	mol %	0.0 %
H_2O	mol %	<5
H_2S, COS	mol %	<0,2
Pressure	kPa	2500 -3500

Gasification science – gas flow inside cavity



$C + ½\ O_2 \rightarrow CO$ $\quad C + CO_2 \rightarrow 2\ CO$

$C + O_2 \rightarrow CO_2$ $\quad C + H_2O \rightarrow CO + H_2$

$H_2 + O_2 \rightarrow H_2O$

Water-gas shift:

$CO + H_2O \rightarrow CO_2 + H_2$

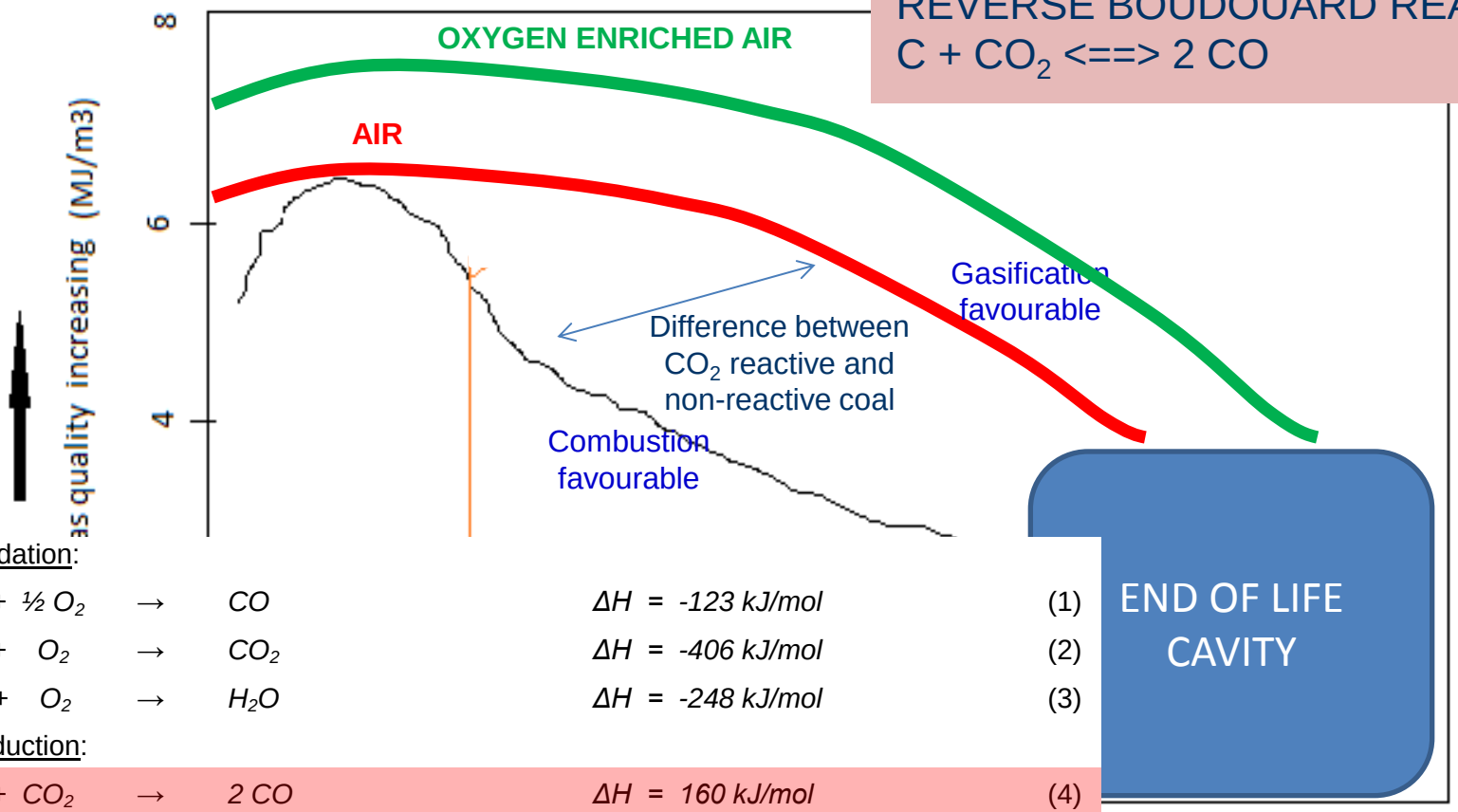
Methane formation:

$C + 2\ H_2 \rightarrow CH_4$

$CO + 3H_2 \rightarrow CH_4 + H_2O$

$3C + 2H_2O \rightarrow CH_4 + 2\ CO$

Gasification science – gas quality control



Oxidation:

$C + ½ O_2$	→	CO	$\Delta H = -123$ kJ/mol	(1)
$C + O_2$	→	CO_2	$\Delta H = -406$ kJ/mol	(2)
$H_2 + O_2$	→	H_2O	$\Delta H = -248$ kJ/mol	(3)

Reduction:

$C + CO_2$	→	$2\ CO$	$\Delta H = 160$ kJ/mol	(4)
$C + H_2O$	→	$CO + H_2$	$\Delta H = 119$ kJ/mol	(5)

Water-gas shift:

$CO + H_2O$	→	$CO_2 + H_2$	$\Delta H = -40$ kJ/mol	(6)

Gasification science – ignition science and coal reactivity

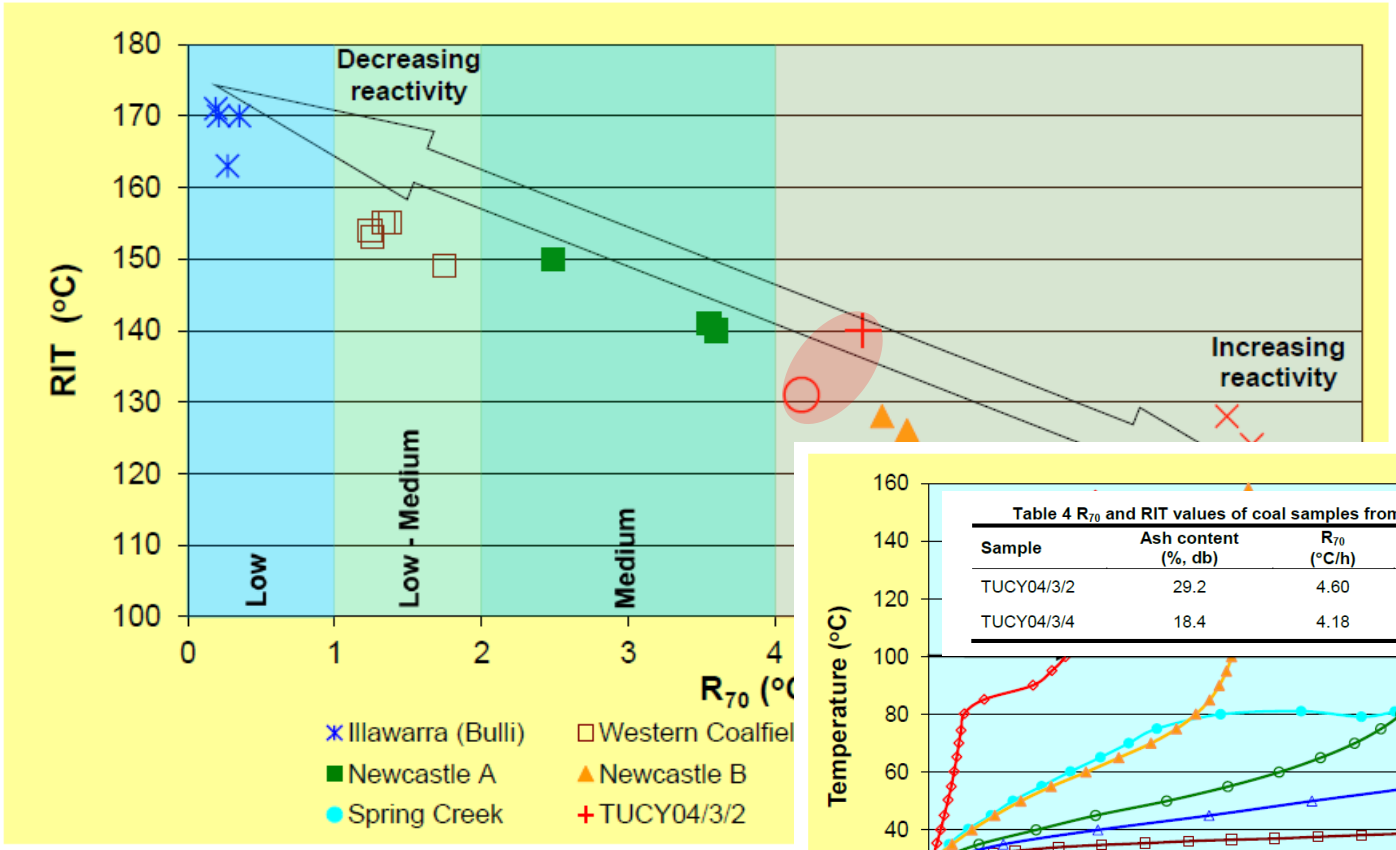
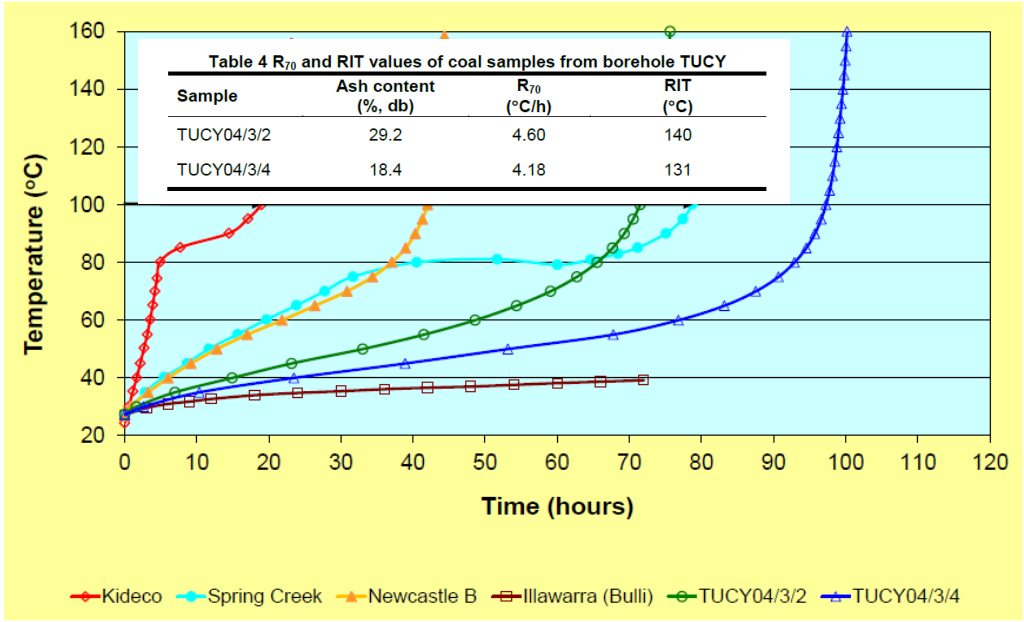
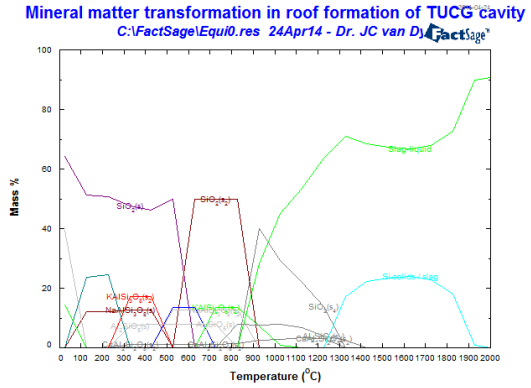


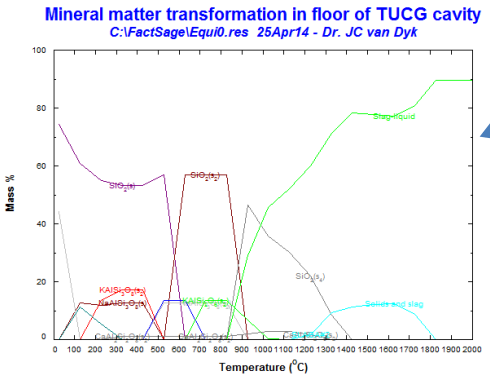
Table 4 R_{70} and RIT values of coal sa

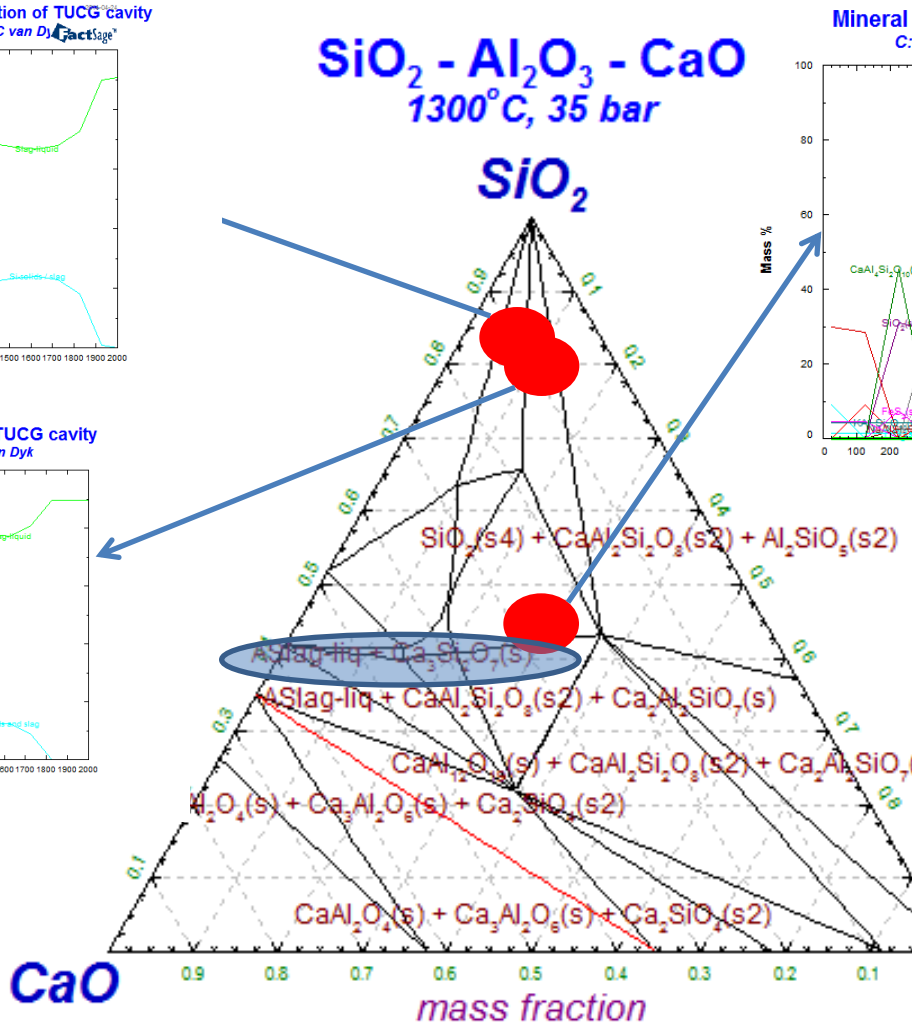
Sample	Ash content (%, db)
TUCY04/3/2	29.2
TUCY04/3/4	18.4

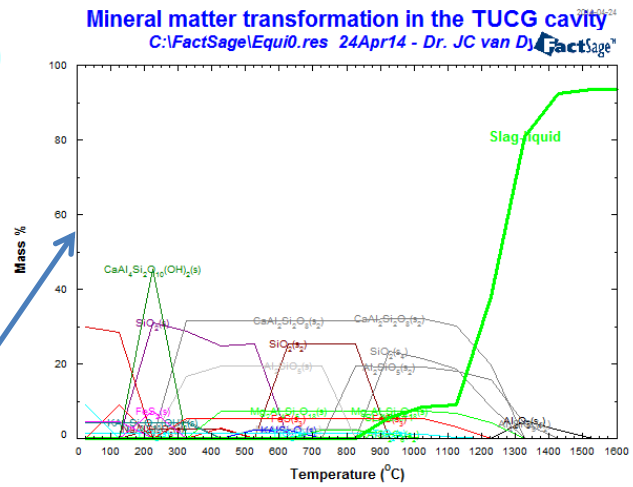


Gasification science – mineral transformation and ash behaviour

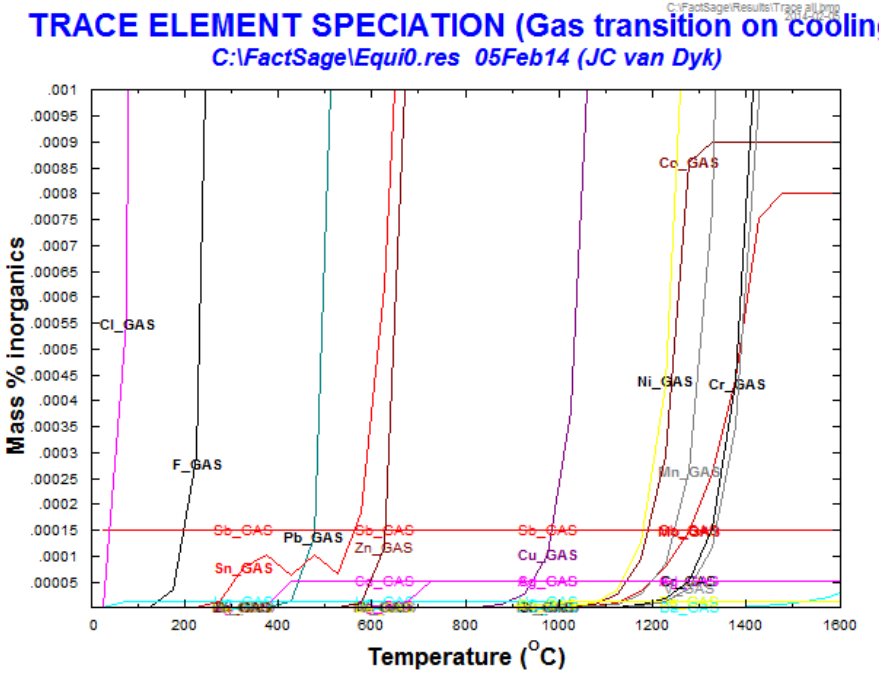


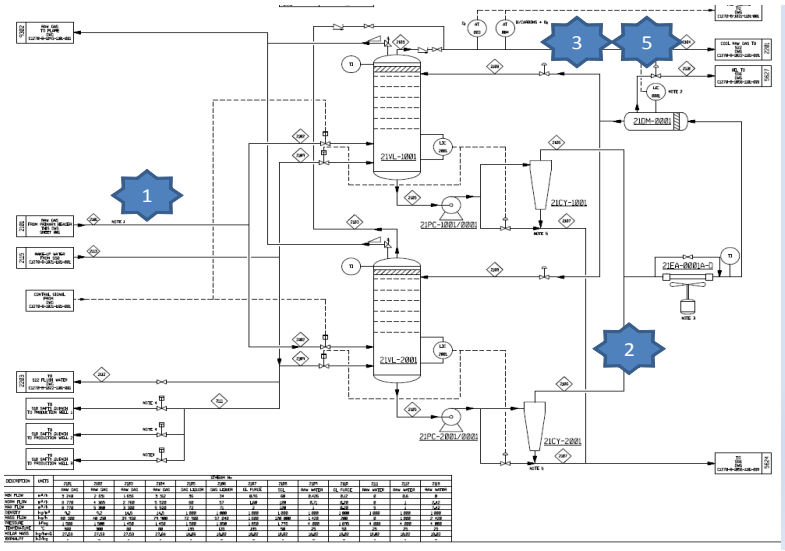






Gasification science – trace element speciation





1 - RG OUT

2 - GL and tar

3 - Dry RG

4 - RG underground cavity

5 - Dry RG

mg/hr	Si	Al	Fe	P	Ti	Ca	Mg	K	Na_2
1 - Stream 2101 RG OUT 250	9.68791E-33	2.3318E-30	3.9809E-08	3.7464E-25	3.3692E-39	9.3736E-23	3.0269E-17	1.0296E-12	1.7492E-14
2 - GL and tar at 135	0	-6.2888E-59	2.2185E-06	-2.1575E-53	0	-2.7939E-44	-2.5694E-36	-1.7283E-28	-4.397E-30
3 - Dry RG at 80	8.25733E-55	9.7359E-49	3.1277E-17	3.1836E-45	4.4996E-62	6.3548E-36	1.857E-29	7.8707E-24	1.1467E-25
4 - RG underground cavity at 300	6.93976E-28	2.1161E-26	2.255E-06	1.323E-20	3.8841E-34	6.37E-20	8.1869E-15	1.8524E-10	4.078E-12
5 - Dry RG at 50	0	6.2888E-59	2.2629E-23	2.1575E-53	0	2.7939E-44	2.5694E-36	1.7283E-28	4.397E-30
In cavity or ash matrix	7636513573	4462730338	1040752973	13529289.9	241537607	1417956595	192551273	133820216	68993368.7

Advantages of Africary's commercial UCG technology – positive environmental impact

- UCG power generation produces 25% less CO_2 per MWe and in large scale Combined Cycle mode can reach energy efficiencies of up to 58% compared to current 35%.
- UCG has no dust particulate emissions or ash handling AND little or no leaching of trace elements from ash when operated correctly / optimally
- UCG mining and power generation uses 90% less water
- Less sulphur and heavy metals are released or emitted by the UCG process
- Gas Engines offer higher fuel efficiency (up to 40%), than any boiler operated in SA today (±35%)

Advantages of Africary's commercial UCG technology – positive social impact

- UCG can monetize economically unmineable coal that would be otherwise lost to the SA economy (<26% of coal reserves recoverable with conventional mining…*Source: U.S. Energy Information Administration, "International Energy Statistics: Coal," 2011)*
- New high value jobs created in the drilling, gas processing and gas engine maintenance industries
- UCG projects can be located in economically depressed areas of South Africa, away from current mined areas
- There are no chemicals used in the UCG process as only air and water are used for gasification
- No fracking required and there are no drilling chemicals injected for the boreholes
- Clean Coal Technologies provide a much needed injection of R&D capital with a new industry being developed and creating high value jobs

Take-home message….

Africary is a South African junior BEE mining company focused to develop successful coal mining operations and be an innovative global leader in UCG

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