Coal and climate change

Potential for carbon capture and storage in South Africa

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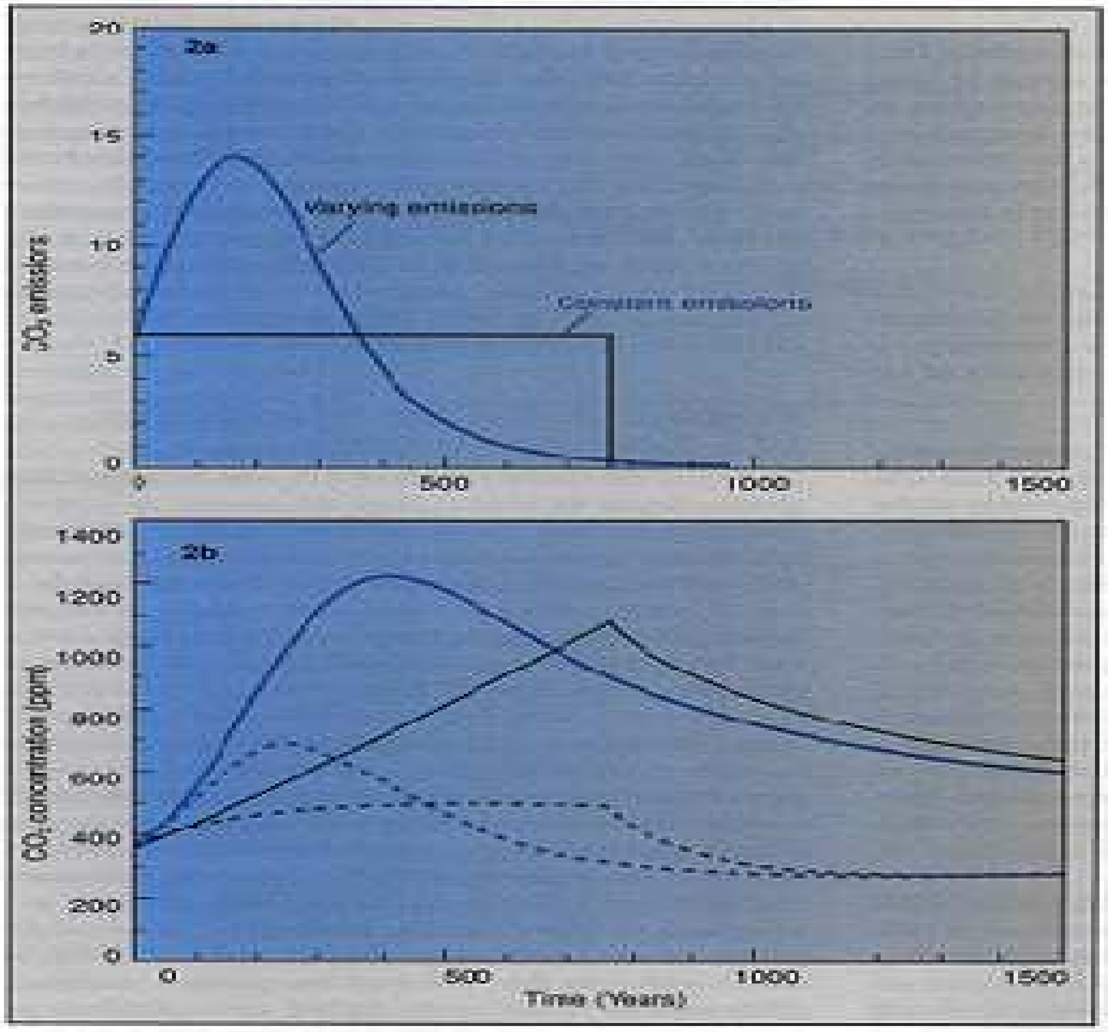
Contents

Projected CO2 emissions and concentrations (US Global change information office)



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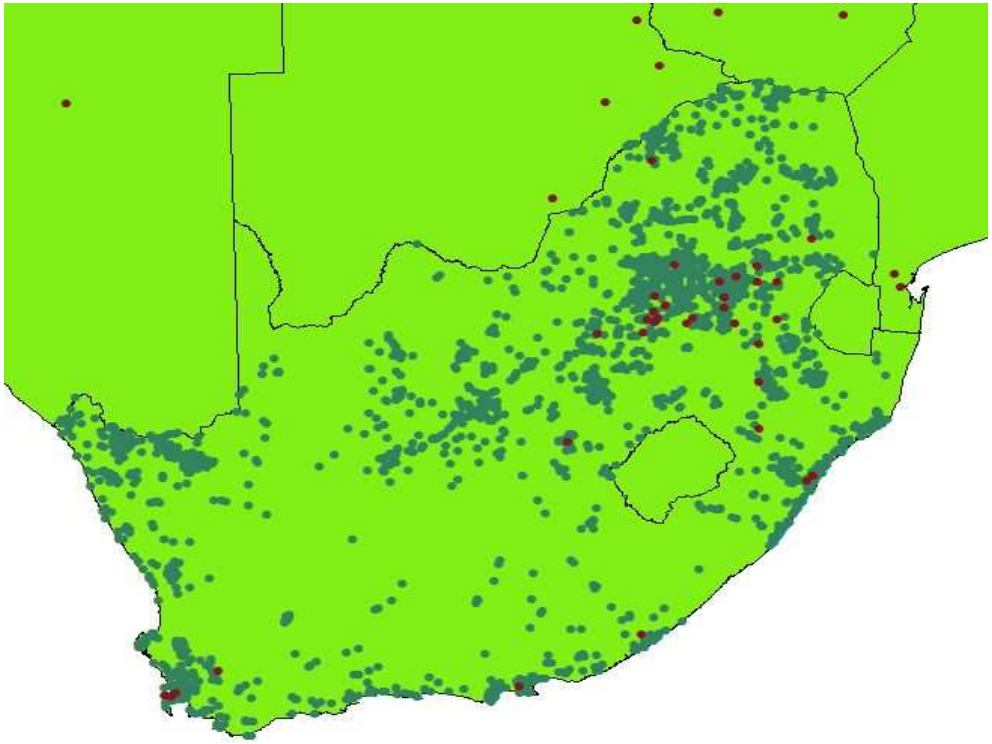
Sources of CO2 in South Africa
CO2 emissions from mines(grey) and power stations(red). CSIR data



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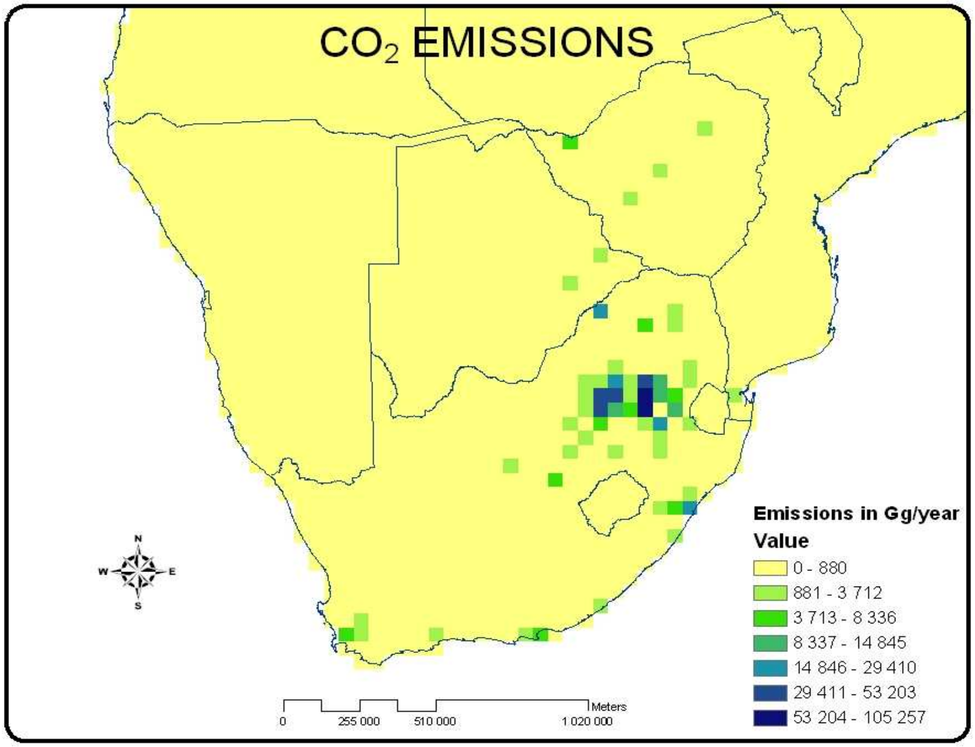
Concentrations of CO2 over RSA (CSIR Data)



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CO_2 capture potential

- Capture from small or non-point sources
  No cost effective technology
- Post combustion capture
  Scrubbing of flue gas with mono-ethanol amine (MEA) solution
- Capture during combustion
  Oxyfuel combustion, high CO_2 concentration
- Pre-combustion capture
  Pre-gasifying, cleaning and CO_2 removal

Year 2000 CO_2 emissions by industry sector

2

	Mt	%
Sequestrable		
Electricity production	161 [Ref 3]	65
Industrial processes	28	11
Other energy	30	12
Manufacturing	30	12
Total	249	100
Non sequestrable		
Waste	10	6
Agriculture	48	27
Fugitive	42	24
Transport	40	22
Heat production	37	21
Total	178	100
Total	**427**	

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CO2 emissions from Eskom power stations

Power station	Location	Power output (MW)	CO_2 emitted (Mt/a)	CO_2 concentration (%)
Hendrina	Hendrina	1338	11	12 – 15
Arnot	Middelburg	1104	9	12 – 15
Kriel	Leandra/Secunda	1992	15	12 – 15
Matla	Leandra/Secunda	2877	22	12 – 15
Duvha	Witbank	2601	19	12 – 15
Lethabo	Vanderbijl	2463	18	12 – 15
Kendal	Kendal	2819	22	12 – 15
Tutuka	Standerton	1023	8	12 – 15
Majuba	Majuba/Volksrust	590	4	12 – 15
Matimba	Ellisras	2715	21	12 – 15
Other		1350	12	12 – 15
Total			161	

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CO2 emissions from Sasol

Plant	Location	CO2 source	CO2 emitted (Mt/a)	CO2 conc. (%)
Sasol 1	Sasolburg	Boilers & heaters	7	10 -15
Sasol 1	Sasolburg	Downstream of Gasifiers	4	90 -98
SSF Sasol 2	Secunda	Boilers & heaters	9	10 –15
SSF Sasol 2	Secunda	Downstream of Gasifiers	14	90 –98
SSF Sasol 3	Secunda	Boilers & heaters	9	10 –15
SSF Sasol 3	Secunda	Downstream of Gasifiers	14	90 –98
Total			57	

Emissions from other industries

Industry Sector	Company	Location	CO_2 Emitted (Mt/a)	CO_2 conc. (%)
Iron and Steel	Iscor	Vanderbijlpark	5.6	10-15
	Iscor	Newcastle	2.2	
	Saldanha steel	Saldanha	2.0	
Non ferrous metals	Alusaf	Richards Bay	1.2	10 -15
	RBM	Richards Bay	0.9	
	Ticor	Empangeni	0.2	
	Xstrata	Rustenburg	0.2	
	Impala platinum	Rustenburg	0.6	
Petroleum refining	Natref	Sasolburg	0.9	10-15
	Sapref	Durban	1.2	
	Enref	Durban	0.9	
	Calref	Cape Town	0.9	
	Petro SA	Mossel Bay	0.4	80 -90
Pulp and Paper	Sappi	KZN, MP	1.6	10-15
	Mondi	KZN	1.2	
Cement	PPC	KZN,GP,WC,EC	2.3	10 -15
Other	Large number of companies	Country wide	8.7	10-15
Total			31.0	

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Cost of CO2 capture in the USA

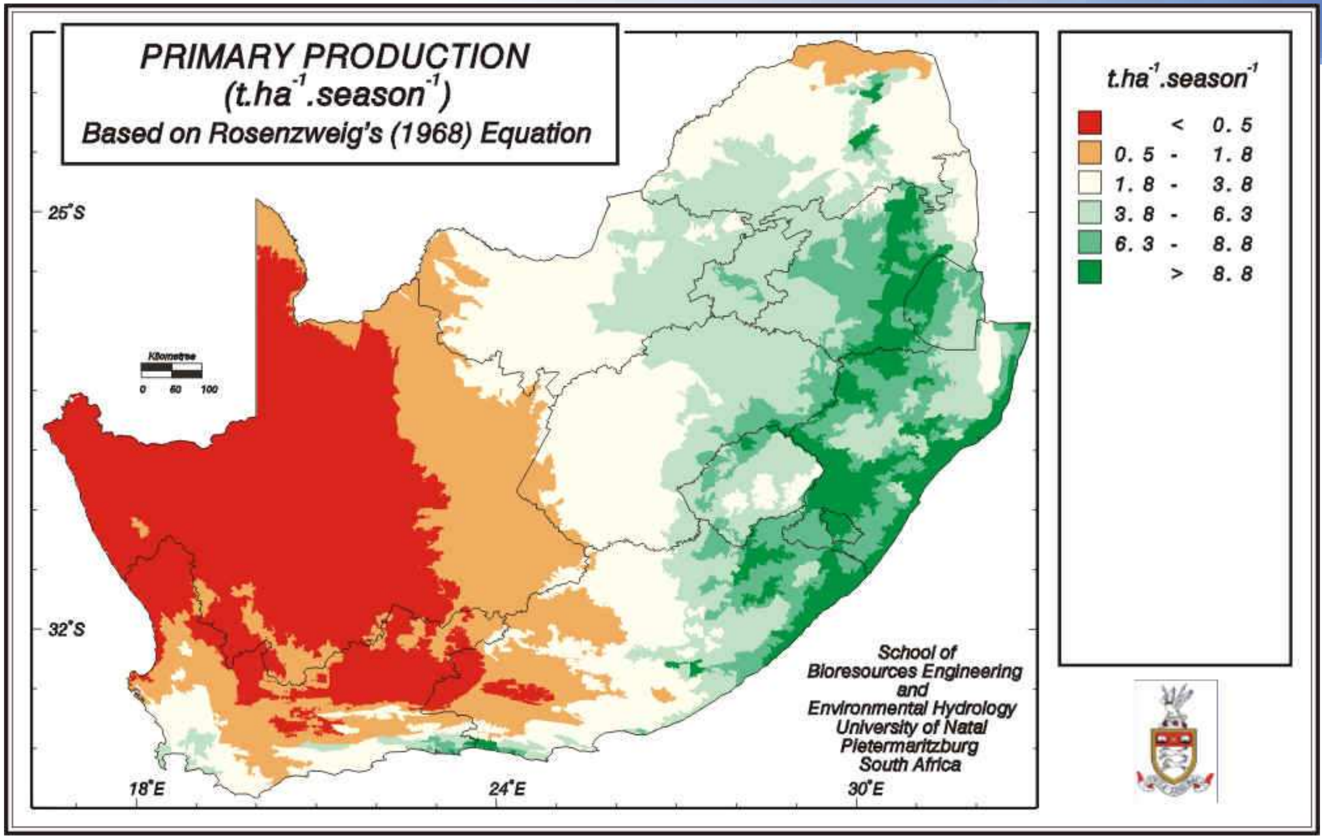
Capture Technology	Technology status	Electricity cost		Capture cost US$/ton CO_2	Total cost US$/ton CO_2	Increase in Electricity Cost (%)
		USc/kWh	US$/ton+ CO_2			
Post combustion	Current	3.1	30.3	26.4	56.8	87
Pre-combustion	Demo plants	4.2	41.2	21.5	62.7	52
In- combustion	Pilot plants*	3.5	34.3	11.7	46.0	34

Biological sequestration

Biological sequestration is the medium-to-long term[1]storage of carbon, derived from the atmosphere, in living and dead plant parts and soil organic matter.

[1] *The Intergovernmental Panel on Climate Change uses an informal guideline of twenty years or more*

Biological sequestration



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Biological sequestration

- There is demonstrated potential for carbon sequestration in all of South Africa's major land ecosystem types, but this statement must be read with the following two cautions:
- Carbon sequestration is a *global* market, and relative to developing country competitors in this potential market, South Africa offers neither a large sequestration opportunity in absolute terms, nor a rapid one, basically because it is overall a dry country, and the moister parts are subject to intense competition between agricultural, water yield and conservation objectives;
- Demonstrating a biophysical potential does not mean that the potential can be economically realised. In particular, low sequestration rates such as characterise available South African environments, impose relatively high proportional transaction costs.

Biological sequestration

Technique	Rate[1] million tons CO_2 /y	Duration[2] Years	Extent[3] ha	Cost[4] R/ton
Options involving an increase in carbon stocks on the land				
Afforestation	3.9	20	330000	-46.60
Reduced tillage	0.4	20	5% of croplands	9.70
Savanna thickening	7.9	20	40% of savannas	0.81
Options involving a reduction of emissions of non-CO_2 GHG emissions				
Reduced cane burning	0.3	unlimited	40% of cane	24.50
Reduction in veld fires	0.7	unlimited	~80% of SA	-77.00
Reduction of emissions from enteric fermentation	6.9	unlimited	~70% of SA	-5.00
Manure management	1.7	unlimited	feedlots	49.00

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Geological sequestration

Geological sequestration is a form of direct sequestration where CO_2 is stored in underground formations, such as depleted oil and gas reservoirs, unmineable coal seams and saline reservoirs. These formations have the capacity, structure, seals, porosity and other properties (i.e. dissolving of CO_2 in groundwater), that make them amenable to decades or centuries worth of CO_2 storage. Such methods should be environmentally effective, socially acceptable and economically feasible and will have their own weaknesses and strengths.

Geological sequestration

- Oil and gas reservoirs

The production from depleted oil and gas reservoirs can be enhanced by 10-15% by pumping CO_2 gas into the reservoir to push out the product. (Enhanced Oil or Gas Recovery or EOR/EGR. The USA is using approx 32 million ton of CO_2 per annum. It is a low cost option because a net revenue arises.

In RSA gas production is about 1.4 billion m3/y. CO_2 storage potential approx 1 million ton of CO_2 /y.

- Mines

  If CO_2 is stored at a pressure of at least 80 bars than the potential is about 10 million ton/y based on current mining activities.

Geological sequestration

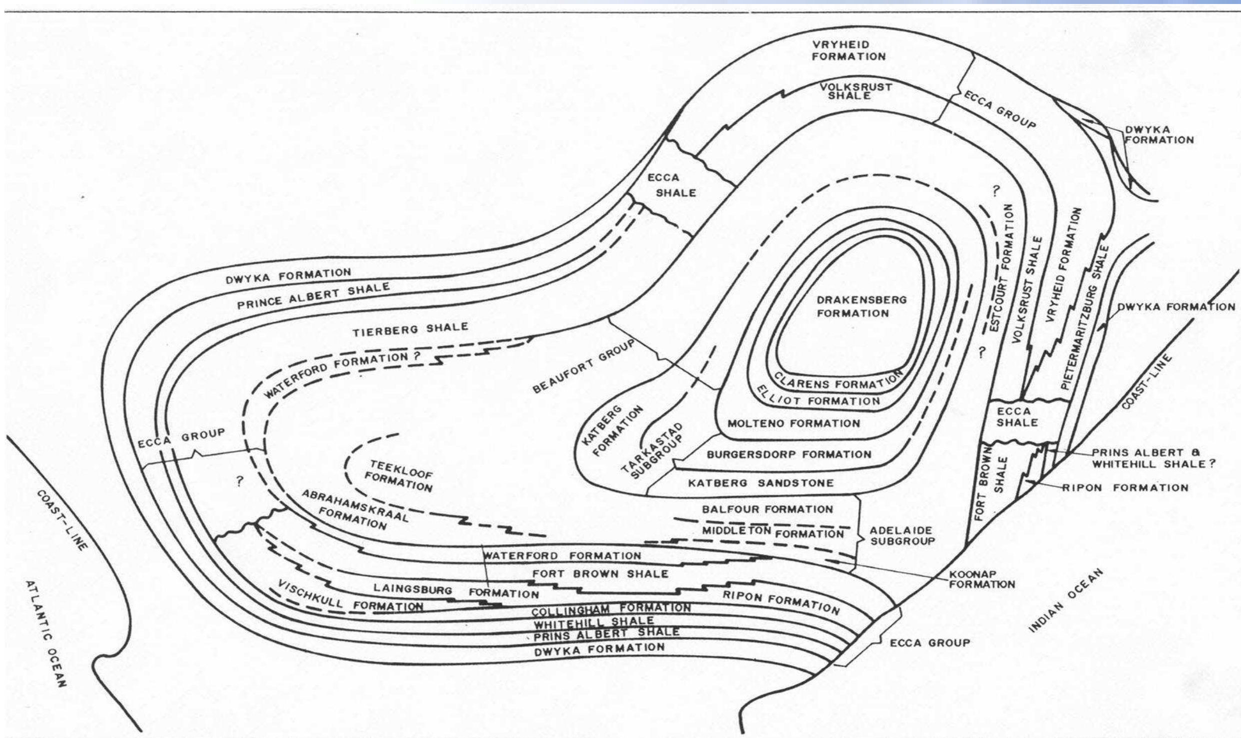

Figure 4: Schematic distribution of lithosratigraphic unit in the main Karoo basin (After SACS, 1980) in (Engineering Geology of Southern Africa, Volume 3 The Karoo Sequence by A.B.A. Brink)

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Geological sequestration

- The eastern margin of the Ecca Formation i.e. the Vryheid Formation (0-520m in thickness) is relatively close to SASOL and a number of power stations. However they are also the same sediments in which the coals are located and injection of CO_2 into these sediments down-dip of the productive coal seams will require careful consideration to avoid sterilising future coal resources.
- The Ripon Formation (1000m in thickness), which occurs along the Eastern Cape Coast may also be suitable, but these sandstones are characterised by low porosity (3-5%) and poor permeability, other research groups (Law, D.D. et al 2001) are investigating potential aquifers that have porosities in the range 6-12%.

Geological sequestration

- The potential storage capacity of the Vryheid Formation is 183750 million ton at >80 bar pressure sufficient for 500 years of South Africa’s emissions. Bearing in mind the poor permeability attributed to these sediments a significantly lower figure is likely to be realistic.
- This figure should be discounted by an order of magnitude to allow for poor storage capacity, geological and other constraints.
- Research is required to obtain numbers with a higher confidence level.

Marine sequestration

- The delivery of a concentrated compressed CO_2 stream to the deep ocean (>1500m), via pipelines or other means

  There might be an opportunity to use the deep sea currents around South Africa.
- The delivery of fertilizers in nutrient poor oceanic environments to help increase the uptake of CO_2

  106C:16N:1P:0.0001Fe (molar ratio’s)

  South Africa is situated relatively close to the Southern Ocean, has good infrastructure (ports and ships) and might therefore be preferred for ocean fertilization projects

Marine sequestration

SAN Sheet	Locality	Nature of contours and distance from coast to 1000 m contour	Current Direction
132	Richards Bay	Shallow contours more irregular. Deeper contours mirror coastline but close up to the north. At Richards Bay 38km. To south approximately 65km	NE to SW
135	Durban	Approximately paralleled to coastline but close up to the south. In north 52km. To south approximately 38km.	NE to SW
125	Port Elizabeth	Approximately paralleled to coastline but the deeper (+200m) contours show a significant “valley” offshore leading into deeper water. From P.E. to this feature is approximately 70km	NNE-SSW
119	Capetown	Shallow contours follow coastline but in deeper waters assume a more NW-SE trend. From Capetown estimated to be in the order of 90km	None shown
118	Saldanha Bay	Maximum depth shown on this sheet is 500m	SE to NW

Risks of ocean sequestration

- Technical Risk is relatively low, trials were successful.
  But there is no clarity on how much CO_2 is retained after fertilization.
- Legislative aspects
  A nation only has jurisdiction over coastal area's
- Environmental consequences
  Very little is known, but calcium carbonate metabolizing organisms are likely to be affected. Ocean fertilization leads to changes in phytoplankton compositions and is likely to affect the food web.

Chemical reactions/capture

- Chemical capture of CO_2 has been postulated as being a permanent, but more expensive, way of capturing the carbon. The technique requires the neutralization of carbonic acid to form carbonates or bicarbonates and replicates but accelerates the natural weathering processes that are exothermic and thermodynamically favoured and result in stable products that are common in nature.

Chemical reactions/capture

- Use in chemical processes possible, but not likely on a large scale.
- Reaction with serpentine or olivine rock require a large amount of rock (2-2.6 ton/ton CO2) and a substantial energy input is required to break the rock, mix the constituents and transport the materials. Large amounts of waste need disposal.
- However certain RSA mine dumps might be usable. This would address at least partly the energy requirements.
- No experimental work is currently carried out in RSA.

Issues

- Most carbon dioxide is produced in a diluted form, except for some streams at Sasol, which are concentrated and it is costly to convert such streams into a concentrated stream.
- There are a relatively small number of point sources where a large percentage of total emissions occur.
- The area's that are potentially most attractive for biological sequestration (high rainfall areas) are largely utilised by agriculture and forestry and the remaining parts are important for the conservation of important ecosystems.
- "Protection" of biological sequestration needs to be done in "perpetuity" but the actual sequestration takes place over a relatively short time period (approximately 50 years or less)

Issues

- Unlike in USA, Canada and Europe no experience exists currently in South Africa regarding CO_2 sequestration in geological structures.
- There is a potential for large-scale storage, but more information regarding the porosity and permeability of potential storage areas is required.
- The technique of oceanic storage appears reasonably well tested internationally, but many issues are poorly understood such as:

- The effectiveness of the technologies
- The cost, both in terms of energy usage as well as financial cost, need more understanding
- The impact of environmental effects
- The applicability of international treaties on the usage of marine reserves and on the discarding of waste materials into the sea.

Conclusions and recommendations

- The highly concentrated CO_2 streams currently produced at Sasol are well suited for CO_2 sequestration without further processing except for pressurising.
- The potential in South Africa for biological sequestration is limited compared with many other countries as the low rainfall in most of the country accounts for a small net primary production.
- Transaction cost for CDM applications can be very large, specifically for small projects.
- The potential for CO_2 sequestration in exhausted gas fields at Mosselbay needs more study also because it may enhance gas recovery.

Conclusions and recommendations

- The potential to use current and exhausted gold and other mines for CO_2 sequestration needs more study, and also potential risks need attention.
- It appears that the porosity and permeability of geological formations is rather low by international standards, but the potential for CO_2 sequestration is large and therefore further study is required.
- Deep Ocean sequestration of CO_2 is potentially possible, however environmental and legal consequences are poorly understood. It is recommended that South Africa stay informed regarding international developments.
- The consequences of ocean fertilisation are not known at presence and it is recommended that South Africa stay informed regarding international developments.

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Overview of sequestration potential

Potential sink	Tonnage (million ton/year)	Duration (years)	Comments
Afforestation Reduced tillage Savanne thickening	3.9 0.4 7.9	20 20 20	An effort is required to store CO_2 in "perpetuity"
Gas reservoirs	1	Very long	There may be enhanced gas recovery
Mines	10	Site specific	More study is required
Vryheid formation Katberg formation	18375 million total 1600 million total	Very long Very long	Relatively poor porosity and permeability, more study is required
Coalbed methane	Small	Long	It may enhance methane recovery
Chemical capture	1 – 5 /year	Indefinite	Large volume of "reactive material" required
Deep ocean	Nearly unlimited	Several hundred years	Deep ocean ecosystems poorly understood
Ocean fertilisation	Not known	Not known	Study required, but not by South Africa

Very long = probably millions of years
Long = probably 100,000' of years

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