Carbon Capture and Storage (CCS) – Strategic Considerations for Eskom

CCS Week

25 October 2011

Barry MacColl – Research, Test and Development
Brian, What’s your sense of the Quality of our conversation on this? – EXCO, BOARD, STAKEHOLDERS? Mpho (Makwana)

Steve (Lennon), We should arrange an update workshop with Board Sustainability for CCS. Get McKinsey to share latest research with us. Brian (Dames).

Wendy (Poulton), Pls action, thanks, Steve.
CCS just one part of the Eskom Emission Reduction Scenarios
South Africa’s Long Term Mitigation Strategy (LTMS) includes moderate CCS targets

<table>
<thead>
<tr>
<th>Mitigation action</th>
<th>Model parameters</th>
<th>Time-scale</th>
<th>Ref. goal</th>
<th>Mit. goal</th>
<th>Quantity</th>
<th>Remaining comment/ qualifications</th>
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<tbody>
<tr>
<td>Energy supply</td>
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<tr>
<td>Renewable electricity action</td>
<td>15% of electricity dispatched from domestic renewable resources by 2020, and 27% by 2030, from South African hydro, wind, solar thermal, landfill gas, PV, bagasse/pulp and paper</td>
<td>2030</td>
<td>27%</td>
<td>(remains at least 27% to end of period)</td>
<td>Total electricity dispatched</td>
<td>Linear extrapolation of 15% by 2020 gives 27% by 2030</td>
</tr>
<tr>
<td>Nuclear energy action</td>
<td>27% of electricity dispatched by 2030 is from nuclear, either PBMRs or conventional nuclear PWRs – model optimised for cost etc</td>
<td>2030</td>
<td>27%</td>
<td>Total electricity dispatched</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaner coal for electricity action</td>
<td>27% of electricity dispatched by supercritical coal and/or IGCC coal technologies by 2030; first plant could be commissioned by 2015</td>
<td>2030</td>
<td>27%</td>
<td>Total electricity dispatched</td>
<td></td>
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<tr>
<td>Limited CCS action</td>
<td>A cap is placed on the amount of CO₂ which can be stored annually, starting with 1 Mt in 2015, and reaching a peak of 20 Mt in 2024. Technologies with CCS include SCC, new PF, IGCC and CCGT.</td>
<td>2024</td>
<td>20 Mt</td>
<td>Annual CCS storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon/GHG emissions tax</td>
<td>R100 (2003 Rands) per ton of CO₂ from electric power plants, introduced from 2008</td>
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Carbon Capture, Transport and Storage

1. Conventional coal-fired power plants release CO₂ directly into the atmosphere. Plants equipped with CCS will capture much of the CO₂ instead.

2. Liquid CO₂ can be transported by pipeline or truck.

3. CO₂ can be injected and stored deep underground.

Depleted oil or gas reservoirs

Alternative possible locations for CO₂ storage

Unmineable coal beds

Deep saline aquifer

Seal rock

Groundwater
Common Capture Techniques

Vattenfall’s 30 MW oxy fuel carbon capture unit

Huaneng - 2000-3000 Nm3/h
China’s 1st Post Combustion CO2 Capture Pilot Plant
Carbon Capture Requires Extensive Plant Changes

An Engineering and Economic Assessment of Post-Combustion CO2 Capture for 1100°F Ultra-Supercritical Pulverized Coal Power Plant Applications
Phase II Task 3 Final Report
EPRI Report 1017515
In March 2008 a revised RoD was issued for Kusile Power Plant which included a requirement for Kusile to be built “Carbon Capture Ready”.

The way this condition was expressed, reflected recognition for:

- the initial power plant design (pulverised coal)
- the international level of technology development (several options under development)
- the status of local information with respect to storage potential (no atlas at that time)

The IEA’s definition, in 2007, that “a CO₂ capture-ready power plant is a plant which can include CO₂ capture when the necessary regulatory or economic drivers are in place” was used to identify the essential pre-requisites.

Stipulating CCR in the RoD is not considered to be a sufficient regulatory framework for the actual deployment of CCS – transport and storage are still lacking.

Particulate matter control, SOx levels, plant layout (access to flue gas, scrubber, power, compression and cooling) and land requirements have been factored into the design.

### Table 2. Revised Balanced scenario capacity

<table>
<thead>
<tr>
<th></th>
<th>Total generating capacity in 2030</th>
<th>Capacity added (including committed) from 2010 to 2030</th>
<th>New (uncommitted) capacity options from 2010 to 2030</th>
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<tbody>
<tr>
<td></td>
<td>MW %</td>
<td>MW %</td>
<td>MW %</td>
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<tr>
<td>Coal</td>
<td>41074 48.2</td>
<td>16386 31.4</td>
<td>6253 16.3</td>
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<tr>
<td>OCGT</td>
<td>9170 10.8</td>
<td>6770 13.0</td>
<td>5750 15.0</td>
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<tr>
<td>CCGT</td>
<td>1896 2.2</td>
<td>1896 3.6</td>
<td>1896 5.0</td>
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<tr>
<td>Pumped Storage</td>
<td>2912 3.4</td>
<td>1332 2.5</td>
<td>0 0.0</td>
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<tr>
<td>Nuclear</td>
<td>11400 13.4</td>
<td>9600 18.4</td>
<td>9600 25.1</td>
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<tr>
<td>Hydro</td>
<td>5499 6.5</td>
<td>3399 6.5</td>
<td>3349 8.8</td>
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<tr>
<td>Wind¹</td>
<td>11800 13.8</td>
<td>11800 22.6</td>
<td>11000 28.8</td>
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<tr>
<td>CSP</td>
<td>600 0.7</td>
<td>600 1.1</td>
<td>400 1.0</td>
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<td>PV</td>
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<tr>
<td>Other</td>
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<tr>
<td><strong>Total</strong></td>
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<td></td>
<td>57460</td>
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</table>

Notes:  
1. Wind includes wind, wave, tidal and other renewable wind technologies.  
2. Committed generation includes committed, in construction and under construction.  
3. Coal = 41074 + 16386 = 57 460  
6253 of this is ‘new’ coal  
5000 of this if we exclude self generation  
i.e. 9% is the new build opportunity from 2027 onward.  
91% would need to be retrofit.  
Question – where should we target for CCS?  
Question – Who will build the 5000MW after 2027?
### Efficiency penalty imposed by capture

#### EPRI Overview: Table 1

<table>
<thead>
<tr>
<th></th>
<th>Reference USPC</th>
<th>RETROFITTED PCC Plant with MHI’s Current KS-1 Solvent Offering</th>
<th>NEW BUILD PCC Plant with MHI’s Current KS-1 Solvent Offering</th>
<th>EPRI Projected NEW BUILD PCC Plant with Potential Improvements Incorporated (*)</th>
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<tbody>
<tr>
<td>Gross Power Output, kW</td>
<td>815,220</td>
<td>704,920</td>
<td>724,920</td>
<td>765,000</td>
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<td>Auxiliary Load, kW</td>
<td>65,218</td>
<td>163,678</td>
<td>163,678</td>
<td>164,000</td>
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<td>Net Power Output, kW</td>
<td>750,002</td>
<td>541,242</td>
<td>561,242</td>
<td>601,000</td>
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<td>Net Plant heat Rate, BTU/KWh (HHV)</td>
<td>8,889</td>
<td>12,318</td>
<td>11,895</td>
<td>11,100</td>
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<tr>
<td>Net Plant Efficiency, % HHV</td>
<td>38.4</td>
<td>27.7</td>
<td>28.7</td>
<td>30.7</td>
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</table>

(*) Note: The EPRI Projection is not a current technology suppliers offering but is essentially based on future cost reductions from economies of scale, ongoing process technology improvements and the envisaged reduction of process contingencies.
An expensive investment with wide variance

CCS overall cost journey – reference case
€/tonne CO₂ abated; rounded to €5; European rollout scenario

Ranges for technology / fuel and onshore / offshore combinations (reference cases)

Highest

Lowest

Note: Cost for other CCS options (e.g., coal retrofit, industry) will vary

Source: McKinsey – Assessing the Economics
Capture is the most expensive component

Total cost of early commercial projects – reference case
€/tonne CO₂ abated; ranges include on- and offshore

Assumption
- CO₂ capture rate of 90-92%
- CCS efficiency penalty of 7-12% points
- Same utilization as non-CCS plant (86%)
- CO₂ compression at capture site
- Transport through onshore/offshore pipeline network of 200/300 km in supercritical state with no intermediate booster station
- Use of carbon steel (assumed sufficiently dry CO₂)
- Injection depth of 1,500 m in supercritical state
- Use of carbon steel (assumed sufficiently dry CO₂)
- Vertical well for onshore/ directional for offshore

Source: McKinsey – Assessing the Economics
A carbon market or price changes the economics

Figure 1: The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)

Includes three levels of EUA costs and is based on the following assumptions: costs for an OPTI plant with CO2 capture; Middle fuel costs; 180 km onshore CO2 transport; Medium storage costs for an onshore deep saline aquifer.


The Eskom project life cycle model (PLCM)

<table>
<thead>
<tr>
<th>PHASE</th>
<th>CONCEPT</th>
<th>DEFINITION</th>
<th>EXECUTION</th>
<th>FINALISATION</th>
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<tr>
<td>STAGE</td>
<td>Opportunity Screening</td>
<td>Feasibility</td>
<td>Planning and Design</td>
<td>Class Out</td>
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<td>Pro Feasibility</td>
<td>Business Plan</td>
<td>Contracting and Procurement</td>
<td>Evaluate</td>
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<td>LEAD ROLE</td>
<td>Core team</td>
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<td>Construction</td>
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<td>ACCOUNTABLE</td>
<td>PDD Project Office</td>
<td>PDD Project Office</td>
<td>CED Project Office</td>
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<tr>
<td>RESPONSIBLE</td>
<td>Core Team</td>
<td>Core Team</td>
<td>CED Project Office</td>
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<td>OBJECTIVES</td>
<td>Objective</td>
<td>Objective</td>
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<td>WORK PACKAGES</td>
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<td>DELIVERABLES</td>
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<td>GOVERNANCE</td>
<td>Governance</td>
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<td>STAGE GATE</td>
<td>CRA DRA Bankable Project ERA</td>
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<tr>
<td>PHASE</td>
<td>STAGE</td>
<td>WORK PACKAGES</td>
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<td>Opportunity Screening</td>
<td>Feasibility</td>
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<td></td>
<td>1.1 Identify Opp for Development</td>
<td>2.1 Establish Core Project Team</td>
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<td>1.2 Screen Opp for Strategic Fit</td>
<td>2.2 Perform Concept Design</td>
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<td>1.3 Identify Needs of Stakeholders</td>
<td>2.3 Perform SH Needs Assessment</td>
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<td>1.4 Review &amp; Collect Supporting Data</td>
<td>2.4 Perform Basic Inf Assessment</td>
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<td>1.5 Prioritize Opp &amp; App Scoring Tool</td>
<td>2.5 Legal &amp; Regulatory Requirements</td>
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<td>1.6 Submit Opp &amp; Invest Portfolio Process</td>
<td>2.6 Partner Selection</td>
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<td>1.7 Develop Pre-Feasibility Plan</td>
<td>2.7 Comm &amp; Fin Structures</td>
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<td>1.8 Assess Stage &amp; Plan Next Stage</td>
<td>2.8 Business Case &amp; Risk Assessment</td>
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<td>2.9 Stakeholder Management</td>
<td>3.1 Structure DCO &amp; PMO Contract</td>
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<td>3.10 Project Dev Planning</td>
<td>3.10 Finalize Site Selection</td>
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<td>2.10 Assess Stage 8 Risk Management</td>
<td>3.11 Prepare &amp; Distribute RFPs</td>
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<td>2.11 Screen, Priorities &amp; Release Appr</td>
<td>3.12 Develop Project Plan</td>
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<td>2.12 Assess Stage 8</td>
<td>3.13 Finalize Power Purchase Agmts</td>
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</tbody>
</table>

**ESKOM PROJECT LIFECYCLE MODEL Version 8.0**

- **Project Start-up**
- **Establish PMO & Party Structures**
- **Resolve Com & Fin Issues**
- **Finalize Reg & Legal Approvals**
- **Detailed Proc & Contracting Plan**
- **Detailed Funding & Call-Down Plan**
- **Project Implementation Plan**
- **Assess Stage & Plan Next Stage**
1. Executive Summary
2. Strategic Overview
3. Site (Land & Rights etc.)
4. Site (Technical Selection)
5. Primary Energy
6. Technology
7. Dx/Tx Integration
8. Sustainability
9. Regulatory
10. Commercial
11. Financial
12. Funding
13. Schedule
14. Risks
15. Stakeholder Management
16. Special Issues
So what are the questions these raise?

1. Strategic Overview
   - What is the rest of the world doing?
   - Why should we do CCS?

2. Site (Land & Rights etc.)
   - Do we have sufficient land at each of our sites?
   - Do existing RODs cover additional plant installed or will we require new EIAs?
   - Will Eskom be responsible for securing servitudes for gas pipelines? Have these routes been secured?

3. Site (Technical Selection)
   - At which sites would we implement this technology? Are they all suitable?
   - What will it do to station efficiency? And thus what will it do to our reserve margin?
   - What outage duration will be required for retrofit options and has this been factored into the energy plan?
   - What criteria are used to select a site? Efficiency? Age? Net Asset Value? Useful life?

4. Primary Energy
   - Will Eskom be in Coal for the next 80 years?
   - What will be the price of coal in the project timeframe?
   - Will we import power from Coal reserves elsewhere and what does that mean for CCS?
   - Will we replace coal stations with renewable and/or nuclear?
   - What are the water requirements and are they available? At what price?
   - What sorbent volumes are required and are they available? At what price?

5. Technology
   - Are we going to retrofit or apply to new or both?
   - What option will we go for? Scrubbing? Oxyfuel? IGCC?
So what are the questions these raise?

6. Sustainability
   • What is the impact on the environment? Are we sure?
   • Who will have the liability for the CO2?
   • Are there any unintended consequences of the capture, transport and storage process?

7. Regulatory
   • Are we bound to do this by legislation? In the future?
   • Will price increases be accepted by the regulator?
   • Will a carbon tax be applied and at what levels? Will CCS be exempt?

8. Commercial
   • What is the potential supplier base?
   • Are there opportunities for local content?
   • Do we have experienced contractors, consultants, engineers in SA to assist with the build?

9. Financial
   • What will it cost?
   • What is the degree of certainty of cost?

10. Funding
    • Where will we get the money? How will we finance it? Cash flow? Cost of Debt?
    • Is foreign funding available?

11. Schedule
    • When will we start, what is the roll out schedule and how long will the programme take?
So what are the questions these raise?

12. Risks
   • All of the above! Cost, water, technology, storage, liability, effect on existing production etc. etc. etc.

13. Stakeholder Management
   • What do the people of South Africa feel about this?
   • Will this enhance or damage our reputation?
   • Do we have a structured communication plan?
   • Is our Shareholder on board?

14. Special Issues
   • What macro economic effects will this have on SA – local and international trade, competitiveness, jobs?
Early mover in Clean Coal Technologies - perspective on the role of the state/SOE.

- In a conventional commercial market governmental support is often only necessary at the very outset of technology development.
- In the case of an immature market combined with high upfront investment costs and unclear framework setting – CCS is high risk endeavour for industry.
- In this case the government support can be distinctly different by sharing the risk and thus stimulating development and deployment of technology.
- While substantial support is necessary to carry out necessary technology development through industry, the governmental role can be extended to become directly involved in large scale infrastructure projects.
- Through its regulatory body, the state can create a framework more favourable to develop more competitive solutions such that the market forces increase and the governmental engagement decreases.
- The state can also stimulate the utilisation of our abundant coal resources in future cleaner coal generation, through research and development in SOE's
What informs Eskom’s strategic position?

- South Africa has relatively large coal resources and reserves, some uranium, very little hydro potential and negligible oil and gas.
- CCS safely and securely demonstrated on small scale demonstration and niche commercial projects elsewhere – the technology is thus proven.
- Commercial application of the technologies is expected to happen from 2030 onwards.
- CCS technologies are expensive but even with increased capital costs and efficiency impacts, pulverised fuel coal stations with CCS could still be cost-competitive in a carbon constrained regime given the lack of alternatives in South Africa.
- New renewable technologies (solar and wind) are not yet mature for delivering baseload electricity requirements (scale and price).
- Previous scenarios developed by the IEA demonstrate that CCS has a role to play in global greenhouse gas mitigation scenarios, in tandem with energy efficiency, renewables and nuclear deployment. It forms a part of almost every carbon mitigation strategy worldwide.
- Capture technology is being developed internationally and Eskom maintains a network to remain abreast of developments in this field.
- Storage potential has to be determined locally and Eskom has participated in the development of the Carbon Storage Atlas – however, the information in this atlas is still at a very coarse resolution and this remains the biggest question at the moment.
- SA’s future electricity supply is determined by the Dept. of Energy’s Integrated Resource Plan – carbon capture and storage investment decisions will need to be made for all new coal investments post Kusile.
Conclusions – A factual business case!

- Ongoing investigation and investment into the various aspects of carbon capture and storage is supported for diversification of South Africa’s future electricity supply mix.

- New information should be regularly reviewed and integrated into planning processes and investment decisions.

- Eskom has a formal and well defined project investment process that asks hard questions of those proposing new projects.

- There are too many hanging questions that will need definitive answers before Eskom invests large sums of public money in CCS projects.

- Eskom strongly supports a joint industry study that answers some of these questions and seeks to collaborate with others.

- As a public utility, Eskom will implement CCS if the business case is strong and there is proven storage available.

- In the context of the South African energy system investment decisions must factually consider the impacts on environment, society and the economy.
THANK YOU

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Current work and partnerships –
- IEA CCC – International Energy Agency Clean Coal Centre
- CSLF – Carbon Sequestration Leadership Forum
- SACCCS – South African Centre for Carbon Capture and Storage
- EPRI – Electric Power Research Institute, Coal fleet for tomorrow
- SASOL – Regular strategic alignment sessions
- Energy Technology Perspectives - (High Efficiency Low Emissions Coal Roadmap);
- Implementing Agreement on Greenhouse Gas (GHG) R&D (via the Coal Industry Advisory Board, CIAB)
- South African Coal Roadmap

Research Agreements under consideration
- GCCSI - Global Carbon Capture and Storage Institute
- BIG CCS – Norwegian Multinational Research Collaboration
- OCTAVIUS – Optimisation of CO2 Trapping Allowing Verification at Utility Scale (European Commission FP7 cooperation)
## Table 1. Revised Balanced Scenario

<table>
<thead>
<tr>
<th></th>
<th>Committed build</th>
<th>New build options</th>
<th>Decommissioning</th>
<th>Total new build</th>
<th>Total system capacity</th>
<th>Peak demand (net sent-out) forecast</th>
<th>Demand Side Management</th>
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• The composition of the gas-fired flue gas was 7.4-7.7% CO₂, 14.6% H₂O, ~ 4.45% O₂, 200-300 ppm CO, 60-70 ppm NOₓ, and 73-74% N₂.

• The composition of the coal-fired flue gas was 12.5-12.8% CO₂, 6.2% H₂O, ~ 4.4% O₂, 50 ppm CO, 420 ppm NOₓ, 420 ppm SO₂, and 76-77% N₂.