Eskom Biomass Co-firing Project Development

04 November 2014
Eskom Current Context

**Current reality**

**Global climate change focus**
- Global commitments under negotiation with increasing pressure on large developing countries
- SA pledge at Copenhagen Accord - 34% below BAU by 2020 (conditional)

**High GHG emissions**
- Eskom is single largest emitter in SA (45% of national)
- Currently emit ~230 Mt increasing to ~284 Mt post-Kusile

**Coal-heavy energy mix**
- 86% of capacity is coal based
- 6% gas-fired, 4% nuclear, 1% hydro and 3% pumped storage

**Legislated requirement**
- The IRP and National climate change policy limit GHG emissions from the electricity sector.
- Possible introduction of a carbon tax
- Possible industry target of 220-275Mt

**Eskom repose**

**Social responsibility**
- Internal commitment to reduce impact on climate and diversify energy mix
- Assist country achieve climate change and emissions targets
- Improve stakeholder relationships and public perception

**Strategic opportunity**
- Diversify energy mix and gain access to emerging technologies, e.g. emerging renewables energy market
- Alternative options for sustainability and growth with decline in coal
- Untapped “clean” energy supplies in SADC offers growth outside SA
Eskom Greener Energy Mix

- Renewables
  - Wind - Sere Wind Facility 100MW
  - Solar
    - Concentrated Solar Power Technology
    - Photo Voltaic Technology
  - Biomass
  - Municipal Waste to Energy
1. Co-milling of biomass with coal
2. Separate milling, injection in pf-lines, combustion in coal burners
3. Separate milling, combustion in dedicated biomass burners
4. Biomass gasification, syngas combusted in furnace boiler
5. Co-milling of torrefied biomass with coal
6. Gasification of torrefied biomass, syngas combusted in furnace boiler
The initial uptake of biomass co-firing in Eskom should be based on:

- Minimising Risks on plant availability
- Ease of Implementation
- Minimising initial Capital Cost
- Utilising fuels with a large reference base and user support group
- Utilising fuels that meet local and international sustainability criteria (including social, economic and environment)

The option that best fit those requirements initially was co-milling or separate milling of pellets

- Of the biomass fuels available wood based biomass have the largest growth expectation, with the main advantages being their high availability, heat content and easier logistics
- It is the biomass of choice for most European Utilities
- Technical risks tend to be lower than other biomass fuel sources
- Up to 5-10% wood pellet biomass can be co-combusted without significant modifications to the existing plant
- Biomass storage, pre-processing and handling are generally the largest costs associated with conversion into co-firing in a coal plant
Options Selected by Eskom

- Co-firing
  - White wood pellets
    - Co-milling
    - Separate milling
  - Torrefied wood pellets
    - Co-milling
Proposed Reference Site – Arnot Power Station

- $6 \times 400 \, MW_e$ sub-critical PC-fired boilers;
- Closest station to wood-based resources in Mpumalanga, approximately 200 km from Sabie;
- Tangential boiler firing system offering greater flexibility to integrate co-firing option;
- Arnot has both Vertical Spindle and Tube Mills: currently no experience with biomass in tube mills, Eskom to prove;
- Capacity risk is lower than for larger units in the Eskom fleet;
Eskom visited the following EU companies in 2011

- Essent – Amercentrale Power Plant;
- Drax Power;
- Fiddlers Ferry.

At the time all were firing white biomass pellets within either co-milling or separate milling approaches.
Findings of co-milling of white biomass pellets:

- Low percentage biomass co-firing achievable (<10%);
- High volatile, absorbs moisture, low CV, biological degradation;
- Biomass particle size is larger than coal – pneumatic transport issues;
- Reduction in milling plant capacity:
  - Modification to milling plant for biomass;
  - Reduce throughput due to biomass characteristics;
  - Temperature control on milling plant.
- Fire & Explosion protection on plant;
- Health & Safety risk – Dust;
- Drax and Fiddlers Ferry Power Plants have used co-milling initially but have introduced separate milling into their plants and recommend this as their preferred option.
Findings of Separate Milling of white biomass pellets:

• Higher percentage biomass co-firing achievable (10-30%);
• Fuel issues remain;
• Requires additional site footprint:
  • Additional fuel delivery system;
  • Biomass storage silos;
  • Separate screening plant;
  • Separate biomass milling plant;
  • Additional biomass transport systems;
  • Additional biomass firing equipment.
• Higher capital & operational cost;
• Wear issues with biomass milling plant.
Separate Milling Infrastructure Requirements

Additional Fuel Storage

Additional Fuel Delivery

Additional Milling Plant

Screening Plant

Additional Infrastructure
Co-milling of white wood pellets excluded because of the following considerations:

- The poor coal quality at Arnot (and at most Eskom stations) and the resultant high mill utilization may make this option unfeasible, as this may result in load losses;
- The conveyor layout at Arnot means that biomass will be fed to three units (cannot only feed to one unit). This will complicate co-fire management, monitoring and evaluation. Any problems experienced with co-milling will effect three units and the impact can be significant;
- Internationally co-milling is not the technology of choice. Most of the plants used it as a first step for biomass co-firing. All have experienced technical problems with co-milling and most has converted to separate milling;
- Technical problems experienced with co-milling may result in resistance against biomass co-firing from the operators;
- Co-milling present increased health (dust inhalation) and safety (fires and explosions) risks;
- Can only obtain a maximum of 5% co-firing ratio with co-milling.
• **Concept Design**
  - The concept design of the Arnot white pellet separate milling solution was finalized;
  - The geotechnical study was concluded for Arnot Separate Milling Solution.

• **Environmental Impact Assessment**
  - EIA was concluded for Arnot Separate Milling Solution (based on white pelletized fuel);
  - The Basic Assessment EIA Report (BAR) was submitted and environmental authorisation granted (Auth. No.: 12/12/20/2380) for Arnot Separate Milling Solution.

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Decision to proceed with white wood pellets put on hold pending assessment of torrefaction technology options
**Geographical Location of RFI Respondents**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Location</th>
<th>Distance to Arnot</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Biotech Fuels</td>
<td>Howick, KZN</td>
<td>495 km</td>
<td>Leading producer</td>
</tr>
<tr>
<td>2. EC Biomass (IDC)</td>
<td>Coega, Port Elisabeth</td>
<td>1,000 km</td>
<td>Producer but sold out until end 2013</td>
</tr>
<tr>
<td>3. Zebra Pellets (IDC)</td>
<td>Sabi, Mpumalanga</td>
<td>200 km</td>
<td>Mothballed, access to feedstock could be an issue</td>
</tr>
<tr>
<td>4. Renu Energy</td>
<td>30km north of Richards Bay</td>
<td>470 km</td>
<td>Mothballed, access to feedstock could be an issue</td>
</tr>
</tbody>
</table>

**Legend**
- Existing Production Plant
- Mothballed Plant

**Note:** (1) None of the supplier currently have a valid BB-BEE rating, except Superlane 136 (level 3 for Exempt Micro Enterprise)
South Africa and its neighboring countries concentrating on *Woody Biomass (>20% lignin)*

The study focused on the following 6 areas:

- 1 - Biomass availability
- 2 - Logistics
- 3 - Markets
- 4 - Fuel costs
- 5 - Impacts and Risks
- 6 - Regulations
## Torrefied Pellet Evaluation

Global Benchmarking & CSIR study

### Utilities moving towards black pellets as the preferred option

<table>
<thead>
<tr>
<th>Current thinking on biomass</th>
<th>Tests done/planned</th>
<th>What assets to be used</th>
<th>Decision criteria and timelines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RWE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have invested $200m+ in biomass supply chain. More investments are to come.</td>
<td>• Significant experience with biomass firing and co-firing</td>
<td>• Large number of coal plants qualify</td>
<td>• Availability of technology will drive decision to invest in torrefaction capacity</td>
</tr>
<tr>
<td>• Torrefaction enabler of low cost/large scale deployment of biomass</td>
<td></td>
<td></td>
<td>• Have invested in the ownership of Topell Energy</td>
</tr>
<tr>
<td><strong>Vattenfall</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Publicly announced demand for 5-10 million tons/annum of torrefied pellets</td>
<td>• Co-fired 900mt of upgraded biomass to facilitate scale co-firing</td>
<td>• Large number of coal plants qualify</td>
<td>• Availability of technology and test product will drive decision</td>
</tr>
<tr>
<td>• Ambitious program to invest in value chain</td>
<td></td>
<td></td>
<td>• Have invested in the ownership of Topell Energy</td>
</tr>
<tr>
<td><strong>Electrabel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Largest co-firer of wood pellets in the world</td>
<td>• Significant experience with large scale co-firing</td>
<td>• Genk (B, 556 MW-e) and Nijmegen (NL, 600 MW-e) qualify</td>
<td>• Less aggressive than RWE/Vattenfall.</td>
</tr>
<tr>
<td>• Need torrefaction/upgrade of biomass to facilitate larger scale co-firing</td>
<td></td>
<td></td>
<td>• Shareholder in Pacific BioEnergy which whom TE discusses torrefaction</td>
</tr>
<tr>
<td><strong>Dong</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Aware of torrefaction • Show interest in using black pellets</td>
<td>• Significant experience with large scale co-firing</td>
<td>• Various assets qualify</td>
<td>• Wait for technology proof</td>
</tr>
<tr>
<td>• Drax has a100% coal portfolio - no other route to go</td>
<td></td>
<td></td>
<td>• Strong incentive for co-firing in Denmark (€ 25 /MWe)</td>
</tr>
<tr>
<td><strong>Drax</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Publically identified preference for torrefied pellets</td>
<td>• Experience with large scale</td>
<td>• Drax main power plant (4000 MW-e) qualify</td>
<td>• Market size 7 million tons for 2020.</td>
</tr>
<tr>
<td><strong>SSE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Strong commitment for biomass projects • Indicate interest in torrefaction</td>
<td>• Experience with large scale</td>
<td>• Ferrybridge (2345 MW-e) qualify</td>
<td>• Strong incentive in UK (ROC system). Minimum incentive equals $ 4.5/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Require LT supply agreements for black pellets</td>
</tr>
</tbody>
</table>

### Key Points:
- **Invested USD 200 million**
- **Announced demand for 5-10 million tons/annum of torrefied pellets**
- **Largest co-firer of wood pellets in the world**
- **Significant experience with large scale co-firing**
- **Publically identified preference for torrefied pellets**
- **Significant experience with large scale co-firing**
Torrefaction is a process whereby biomass is heated without oxygen, thereby breaking its fibrous structure, removing moisture and volatiles, and giving it coal-like physical properties.

- The torrefaction gases are combusted and the thermal output is used in the drying of the biomass.
- The torrefied material can be pelletized for easier transportation.

65-80% higher energy density than wood pellets.
## Torrefied Fuel Closer to Coal Properties

<table>
<thead>
<tr>
<th></th>
<th>Wood Pellets</th>
<th>Torrefaction Pellets</th>
<th>Charcoal</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (% wt)</td>
<td>30 – 40</td>
<td>7 – 10</td>
<td>1 – 5</td>
<td>10 – 15</td>
</tr>
<tr>
<td>Calorific value (MJ/kg)</td>
<td>9 – 12</td>
<td>15 – 16</td>
<td>20 – 24</td>
<td>30 – 32</td>
</tr>
<tr>
<td>Volatiles (% db)</td>
<td>70 – 75</td>
<td>70 – 75</td>
<td>55 – 65</td>
<td>10 – 12</td>
</tr>
<tr>
<td>Fixed carbon (&amp; db)</td>
<td>20 – 25</td>
<td>20 – 25</td>
<td>28 – 35</td>
<td>85 – 87</td>
</tr>
<tr>
<td>Bulk density (kg/l)</td>
<td>0.2 – 0.25</td>
<td>0.55 – 0.75</td>
<td>0.75 – 0.85</td>
<td>~ 0.20</td>
</tr>
<tr>
<td>Volumetric energy density (GJ/m3)</td>
<td>2.0 – 3.0</td>
<td>7.5 – 10.4</td>
<td>15.0 – 18.7</td>
<td>6.0 – 6.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Dust</th>
<th>Hygroscopic properties</th>
<th>Biological degradation</th>
<th>Milling requirements</th>
<th>Handling properties</th>
<th>Product consistency</th>
<th>Transport cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Hydrophilic</td>
<td>Yes</td>
<td>Special</td>
<td>Special</td>
<td>Limited</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Limited</td>
<td>Hydrophilic</td>
<td>No</td>
<td>Classic</td>
<td>Classic</td>
<td>High</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>Limited</td>
<td>Hydrophobic</td>
<td>No</td>
<td>Classic</td>
<td>Classic</td>
<td>High</td>
<td>Low</td>
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<td></td>
<td>Limited</td>
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<td>Classic</td>
<td>Classic</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table recreated from, Kleinschmidt CP, ‘Overview of international developments in torrefaction’, Kema Netherlands, 2011
With limited knowledge on torrefaction Eskom contracted a Dutch consulting company and biomass experts – DNV GL:

• Techno-economic comparison of wood pellets vs torrefied pellets;
• Full scale test burn methodology;
• Impacts on power plant;
• Studies on fuel sampling & laboratory testing;
• Evaluation of torrefaction technology suppliers;
• Life cycle cost analyses.
Basic Comparison of Levelised Cost of Electricity Generation for Several Options

Cost highly sensitive to feedstock pricing

- Arnot Base No CapEx
- BLENDED Coal & Torrefied Co-firing
- BLENDED Coal & White Co-firing
- Medupi with Capex
- Kusile with Capex and FGD
- Wind without Base Load Backup
- One Green MWh Torrefied
- Ingula Pumped Storage
- One Green MWh White
- Solar Central Receiver 9 hrs Storage

Low Green Chip Pricing

R per Megawatt – Hour
## Developing Technology
### Multiple Competing Technologies and Suppliers

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Technology Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple hearth furnace</td>
<td>CMI-NESA (BE)</td>
</tr>
<tr>
<td></td>
<td>Wyssmont/ Integro Earth Fuels (US)</td>
</tr>
<tr>
<td>Rotary drum</td>
<td>CDS (UK)</td>
</tr>
<tr>
<td></td>
<td>Torr-coal (NL)</td>
</tr>
<tr>
<td></td>
<td>BIO3D (FR)</td>
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<tr>
<td></td>
<td>EBES AG (AT)</td>
</tr>
<tr>
<td></td>
<td>BioEndev(SWE)</td>
</tr>
<tr>
<td>Screw conveyor reactor</td>
<td>BTG (NL)</td>
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<tr>
<td></td>
<td>Biolake(NL)</td>
</tr>
<tr>
<td></td>
<td>FoxCoal(NL)</td>
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<tr>
<td></td>
<td>ETPC (SWE)</td>
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<tr>
<td></td>
<td>Agri-tech producers(US)</td>
</tr>
<tr>
<td>Torbed reactor</td>
<td>Topell (NL)</td>
</tr>
<tr>
<td>Compact moving bed</td>
<td>ECN (NL)</td>
</tr>
<tr>
<td></td>
<td>Torspyd/Thermya (FR)</td>
</tr>
<tr>
<td></td>
<td>Buhler (D)</td>
</tr>
<tr>
<td>(Oscillating) belt reactor</td>
<td>Stramproy(NL)</td>
</tr>
<tr>
<td></td>
<td>NewEarthEco Technologies(US)</td>
</tr>
<tr>
<td>Hybrid (screw + cyclone)</td>
<td>Airex(CAN)</td>
</tr>
<tr>
<td>Fluidized bed</td>
<td>River Basin Energy (US)</td>
</tr>
</tbody>
</table>

**SOURCE:** ECN, KEMA
SOC Collaboration

Joint Alliance

- Sourcing of feedstock.
- Sustainability.
- Social aspects.
- Land use.
- Harvesting.
- Logistics

Biomass supply

Biomass Processing
- Chipping.
- Pelletising & Storage.
- Torrefaction.
- Characterization

Logistics
- Transport from Processing plant to Power Station via Rail and/or Road

Power Generation
- Combustion of biomass for electricity generation.
- Disposal of waste products.
Torrefaction Technology Assessment

- No standardised approach to torrefaction of biomass;
- Assessment based on business potential & development potential versus techno-economic potential;
- Business potential included factors such as development status, planned projects, size & experience and business approach;
- Techno-economics included factors such as investment cost, operational cost, product specification, feedstock flexibility.
SAFCOL Studies

• Completed forestry residue resource quantification and have confirmed sufficient supply available for the demonstration plant from SAFCOL;

• Conducted logistics studies:
  • Pre-processing options;
  • Optimal location of processing plant;
  • Costing.

• Preliminary feedstock costing at processing plant gate.
Eskom Findings

- Technical-economic comparison of torrefied pellets versus white pellets with multiple firing options
  Torrefied pellet were most cost effective

- Characterization of biomass
  Information obtained on EN standards for biomass testing
  Eskom become a participant in laboratory benchmarking
  No product standards yet available for torrefied biomass

- Assessment of plant performance with co-firing of biomass
  Arnot Power Station chosen due to location
  Minimal plant impact
Required Future Activities

- **SOC Collaboration**

  - Joint project development and collaboration for the development of a torrefied wood pellet processing plant between Eskom, SAFCOL and IDC

  - Perform a feasibility study on the conversion of the Zebra Pelet plant to a torrefacaton pellet plant
The Advantages would be Substantial

Reduced CO$_2$ emissions
- Co-firing of green coal could substantially reduce South Africa’s overall CO$_2$ emission
- No major investments beyond green coal production plants required

Job creation in rural Africa
- The green coal production plants will create significant direct jobs
- Job creation will take place at rural areas of the country

Developing the region
- Biomass demand and green coal production will trigger growth in the region
- Investments in transport infrastructure as additional growth driver
Thank You