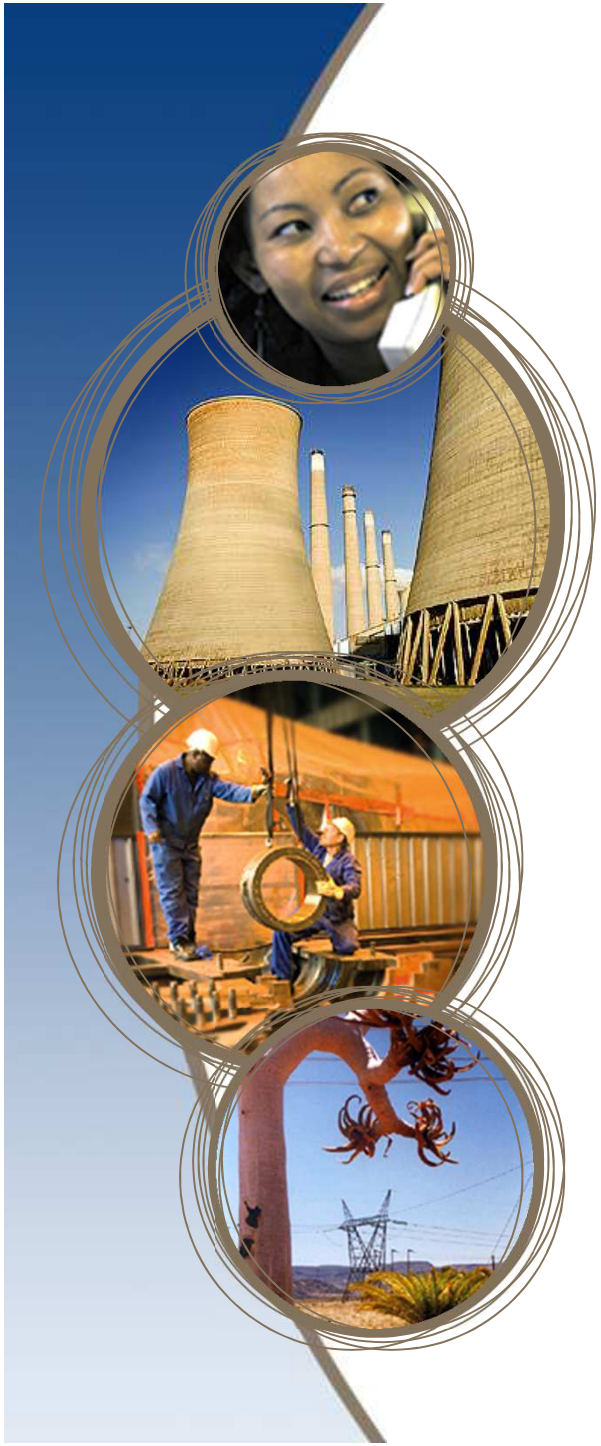


Eskom Biomass Co-firing Project Development

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

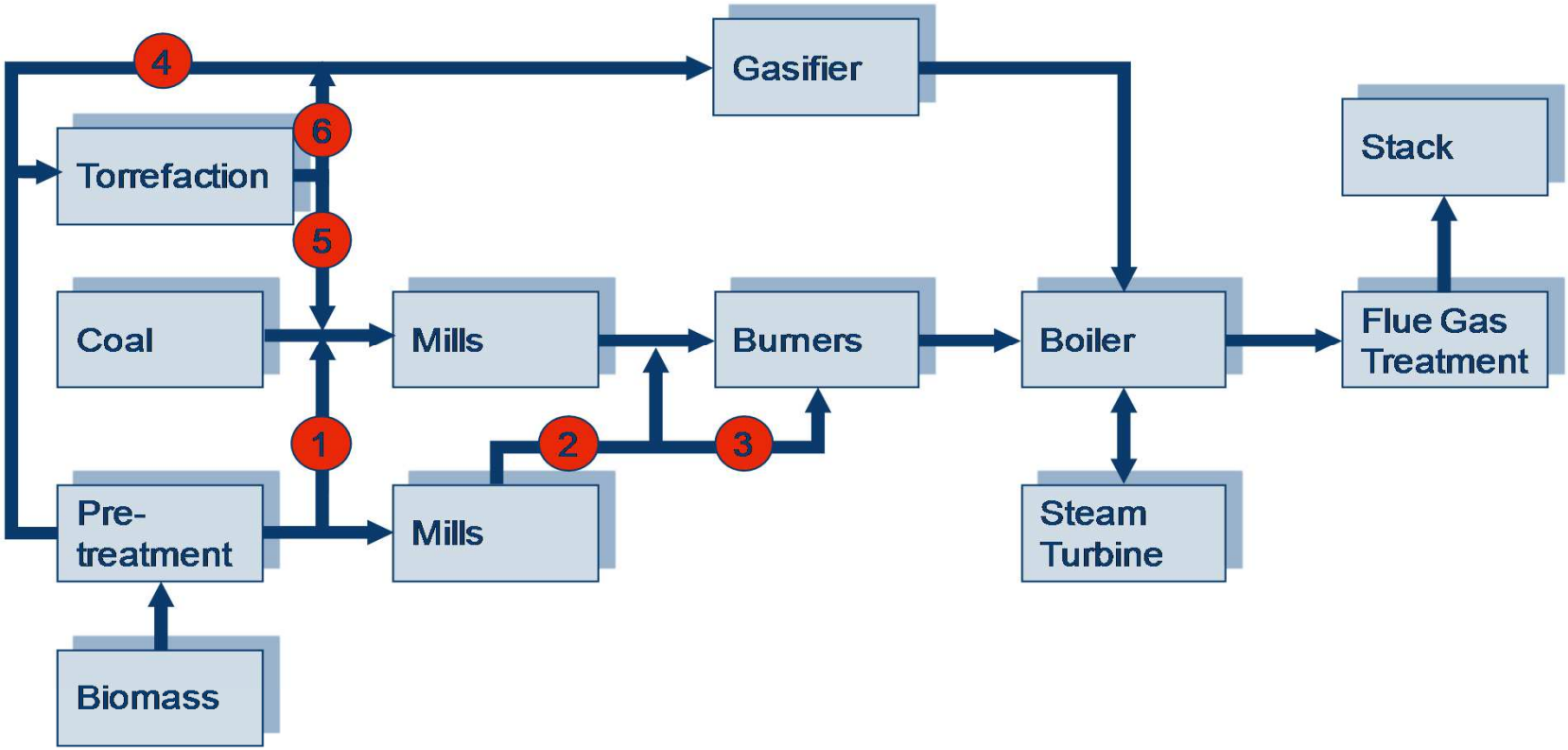
Strategic opportunity

- 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

Biomass Co-firing Pathways



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

Biomass Co-firing Proof of Concept Project Principles

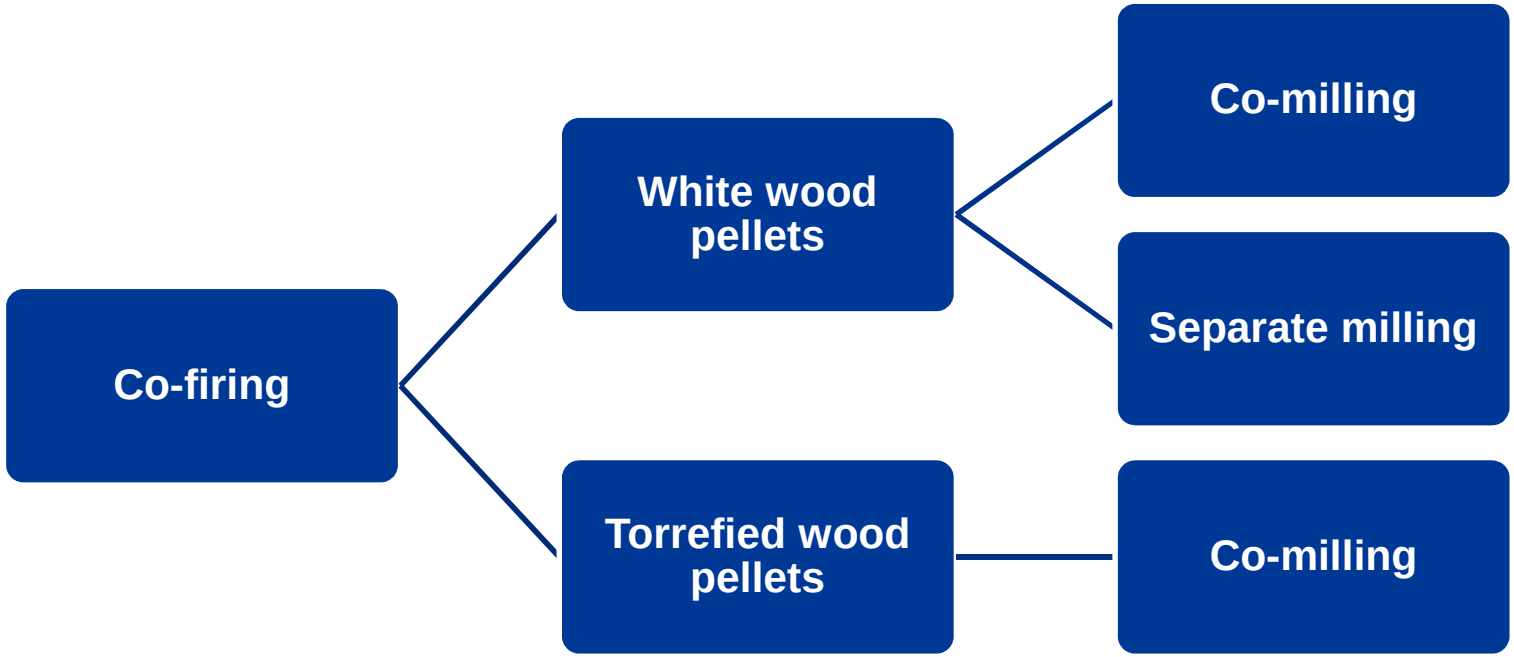
The initial uptake of biomass co-firing in Eskom should be based on:

- 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



Proposed Reference Site – Arnot Power Station

- 6 × 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;

White Wood Pellet Concept Evaluation
EU Benchmark

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.

Co-milling

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 there preferred option.

Separate Milling

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

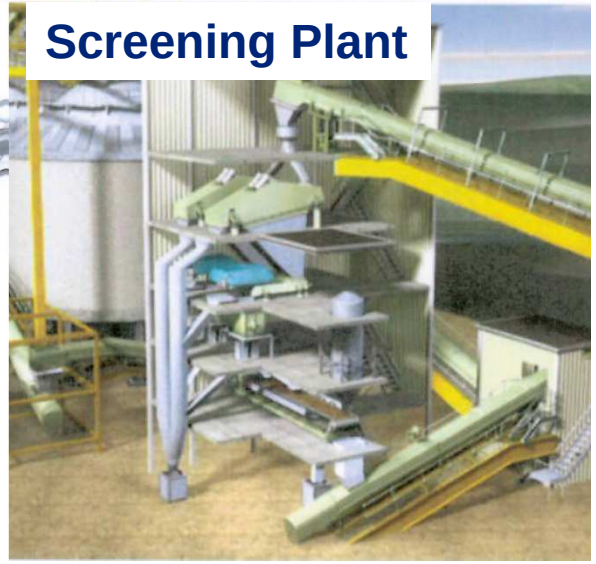
Eskom

Additional Fuel Storage

Additional Fuel Delivery

Additional Milling Plant

Screening Plant



Additional Infrastructure

Separate Milling as Preferred White Wood Pellet Option

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

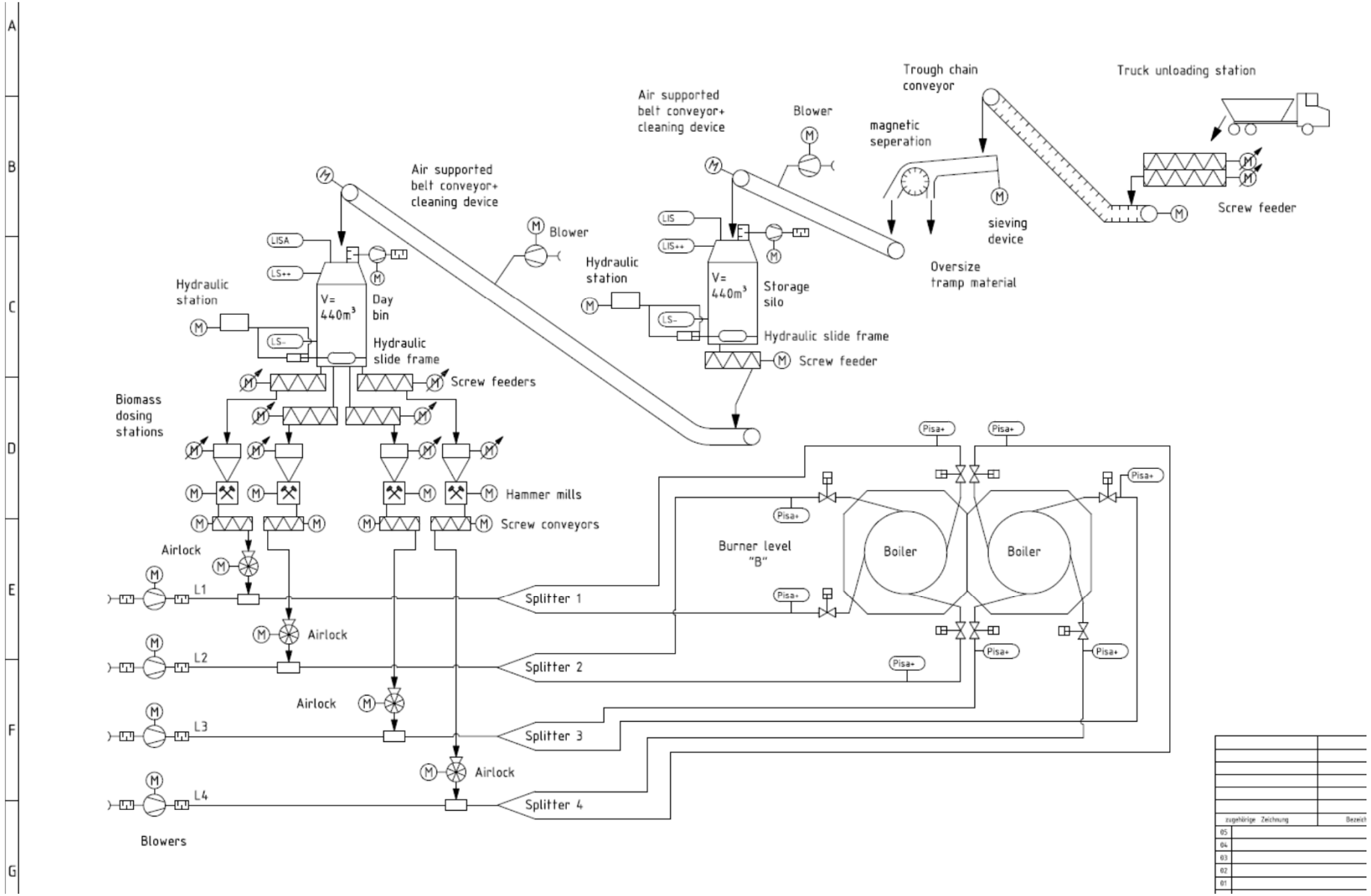
- The poor coal quality at Arnot (and at most Eskom stations) and the resultant high mill utilization may make this option unfeasible, as this may result in load losses;
- The conveyor layout at Arnot means that biomass will be fed to three units (cannot only feed to one unit). This will complicate co-fire 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.

Biomass Co-firing Project
Technical and Regulatory Activities

- **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.

Decision to proceed with white wood pellets put on hold pending assessment of torrefaction technology options

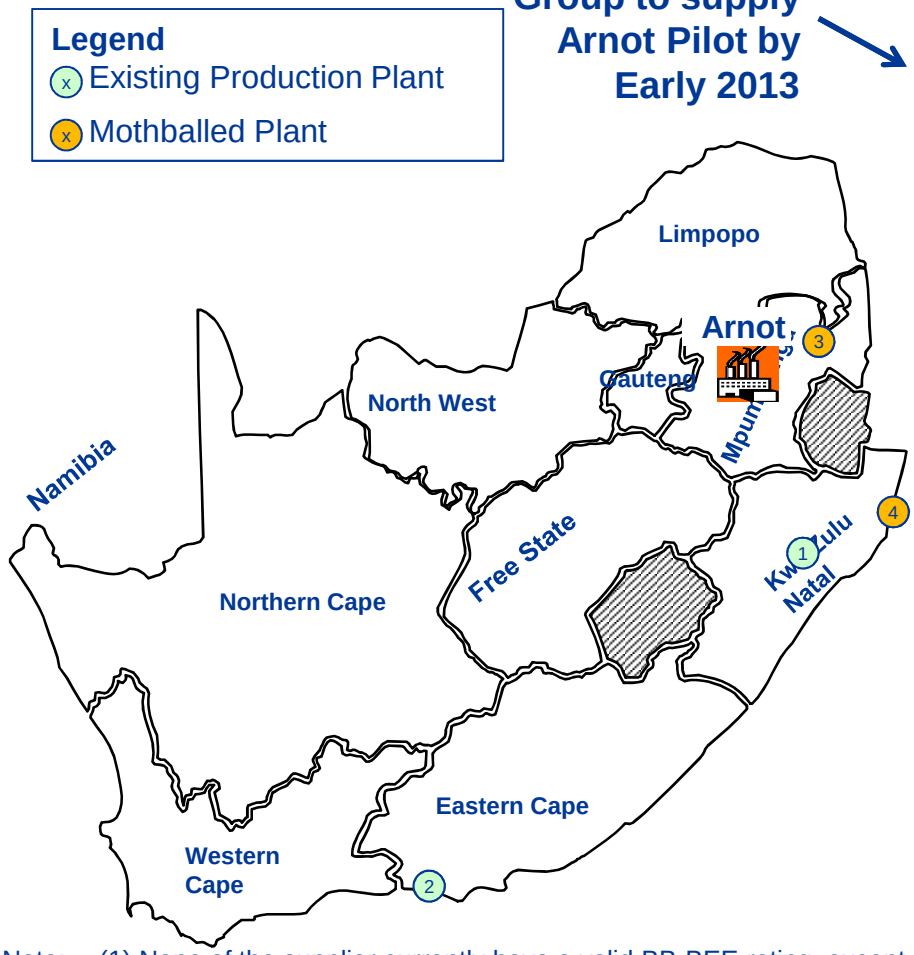
Arnot Separate Milling Concept Design



Wood Pellets SA

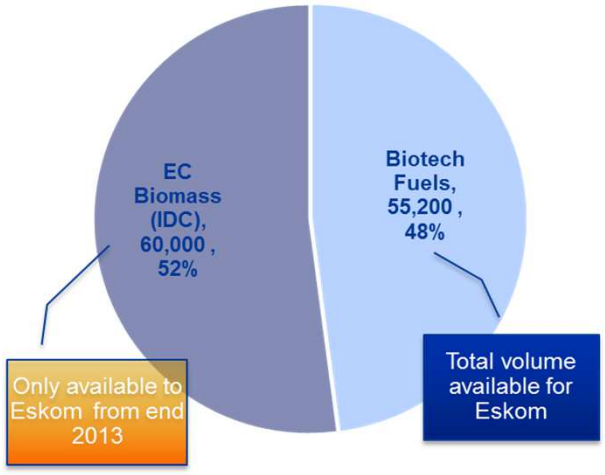
Geographical Location of RFI Respondents

Potential Supplier Group to supply Arnot Pilot by Early 2013



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

Biomass Production
±115,200 tpa produced by 2 suppliers



Note: (1) None of the supplier currently have a valid BB-BEE rating, except Superlane 136 (level 3 for Exempt Micro Enterprise)

Biomass Fuel Source Study - CSIR Scope

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

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

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

Production Principle Torrefaction

Torrefaction gases
(reused for process)

35% of mass
15% of energy

Biomass

Torrefaction
250-300 °C

65% of mass
85% of energy

Pelletization

Bio/Green coal

- 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

	Wood	Wood Pellets	Torrefaction Pellets	Charcoal	Coal
Moisture content (% wt)	30 – 40	7 – 10	1 – 5	1 – 5	10 – 15
Calorific value (MJ/kg)	9 – 12	15 – 16	20 – 24	30 – 32	23 – 28
Volatiles (% db)	70 – 75	70 – 75	55 – 65	10 – 12	15 – 30
Fixed carbon (& db)	20 – 25	20 – 25	28 – 35	85 – 87	50 – 55
Bulk density (kg/l)	0.2 – 0.25	0.55 – 0.75	0.75 – 0.85	~ 0.20	0.8 – 0.85
Volumetric energy density (GJ/m3)	2.0 – 3.0	7.5 – 10.4	15.0 – 18.7	6.0 – 6.4	18.4 – 23.8
Dust	Average	Limited	Limited	High	Limited
Hydroscopic properties	Hydrophilic	Hydrophilic	Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Yes	Yes	No	No	No
Milling requirements	Special	Special	Classic	Classic	Classic
Handling properties	Special	Easy	Easy	Easy	Easy
Product consistency	Limited	High	High	High	High
Transport cost	High	Average	Low	Average	Low

Table recreated from, Kleinschmidt CP, 'Overview of international developments in torrefaction', Kema Netherlands, 2011

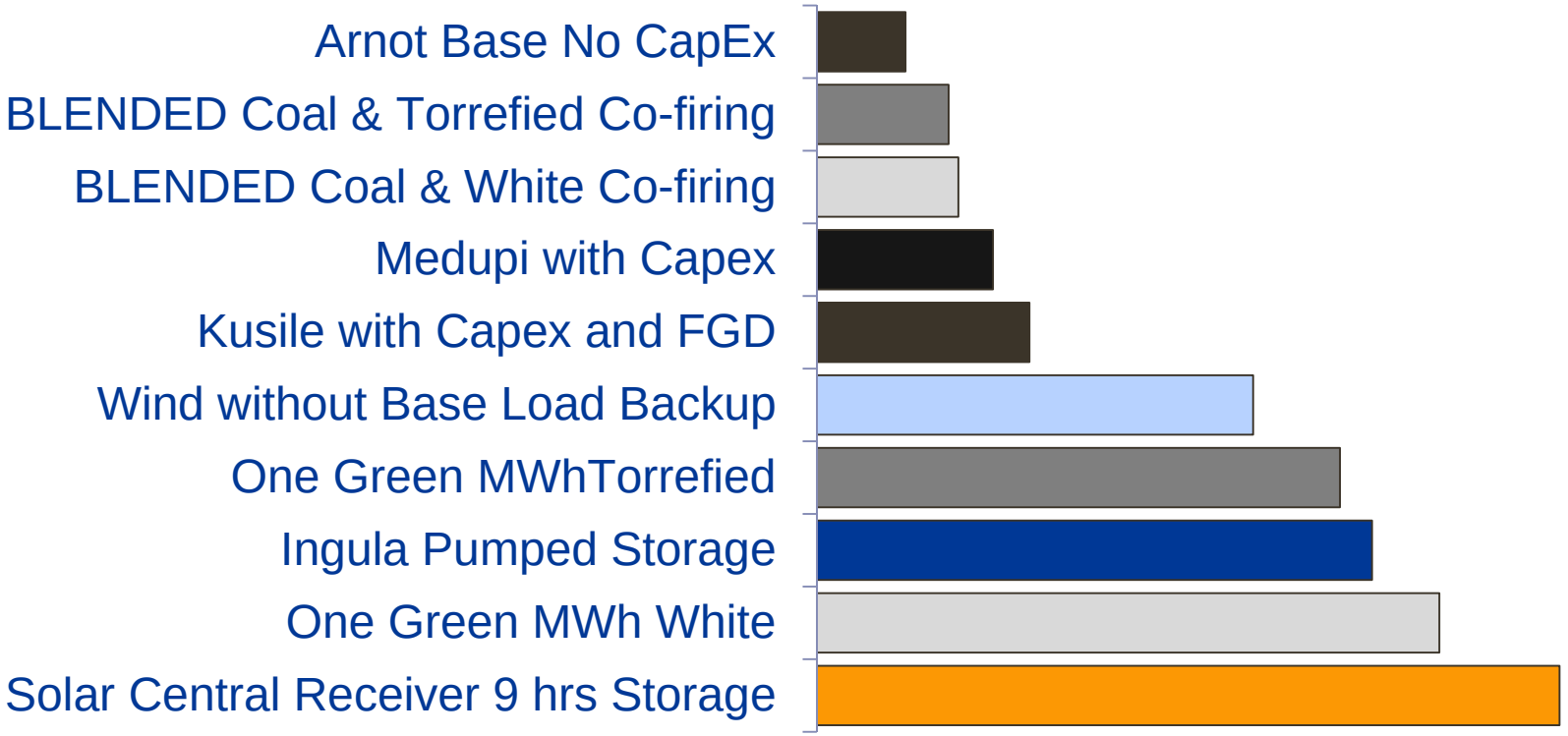
Torrefaction Studies

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

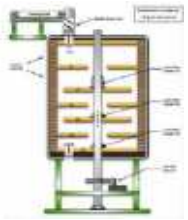
Cost highly sensitive to feedstock pricing

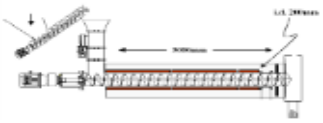


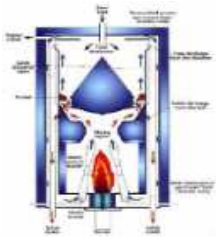
Low Green Chip Pricing

R per Megawatt – Hour

Developing Technology
Multiple Competing Technologies and Suppliers







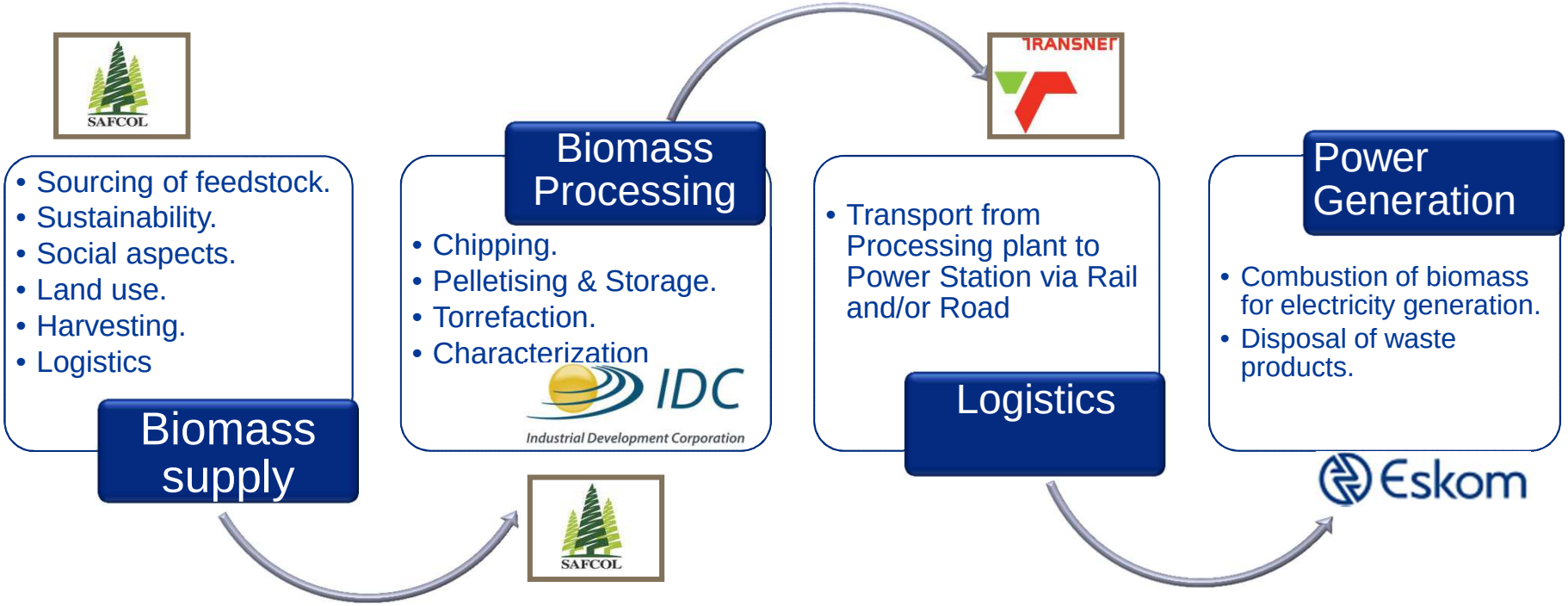
Reactor type	Technology Developer
Multiple hearth furnace	CMI-NESA (BE) Wyssmont/ Integro Earth Fuels (US)
Rotary drum	CDS (UK) Torr-coal (NL) BIO3D (FR) EBES AG (AT) BioEndev(SWE)
Screw conveyor reactor	BTG (NL) Biolake(NL) FoxCoal(NL) ETPC (SWE) Agri-tech producers(US)
Torbed reactor	Topell (NL)

Reactor type	Technology Developer
Compact moving bed	ECN (NL) Torspyd/Thermya (FR) Buhler (D)
(Oscillating) belt reactor	Stramproy(NL) NewEarthEco Technologies(US)
Hybrid (screw + cyclone)	Airex(CAN)
Fluidized bed	River Basin Energy (US)

SOURCE: ECN, KEMA

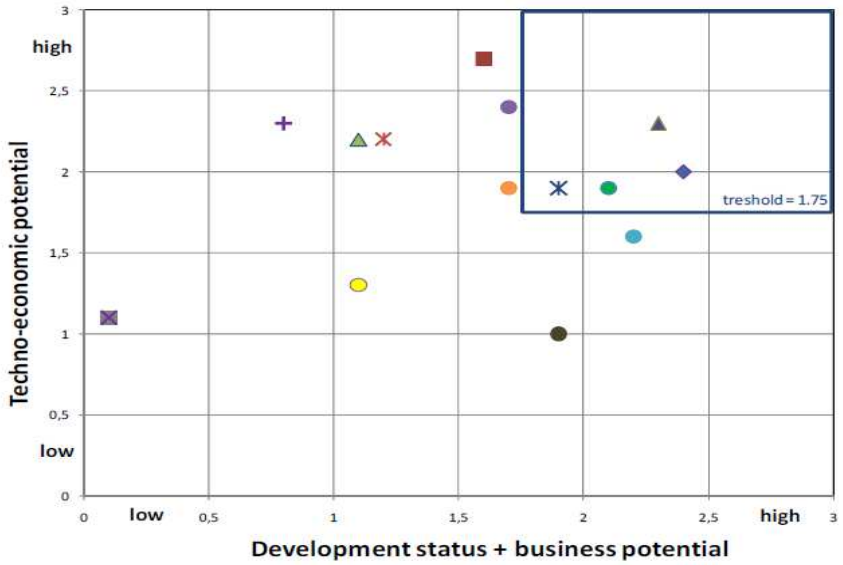
SOC Collaboration

Joint Alliance



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.

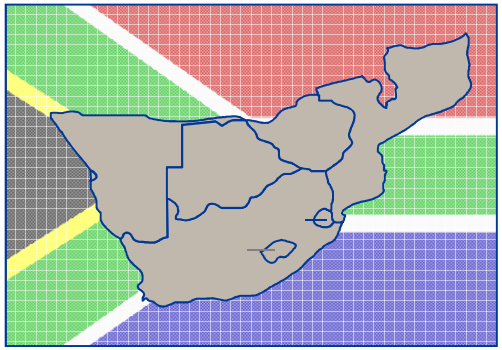
Eskom Findings

- 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 substaintially 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 trans-port infrastructure as additional growth driver

Thank You