ENERGY

Biomass co-firing and full conversion

Opportunities for bioenergy in South Africa

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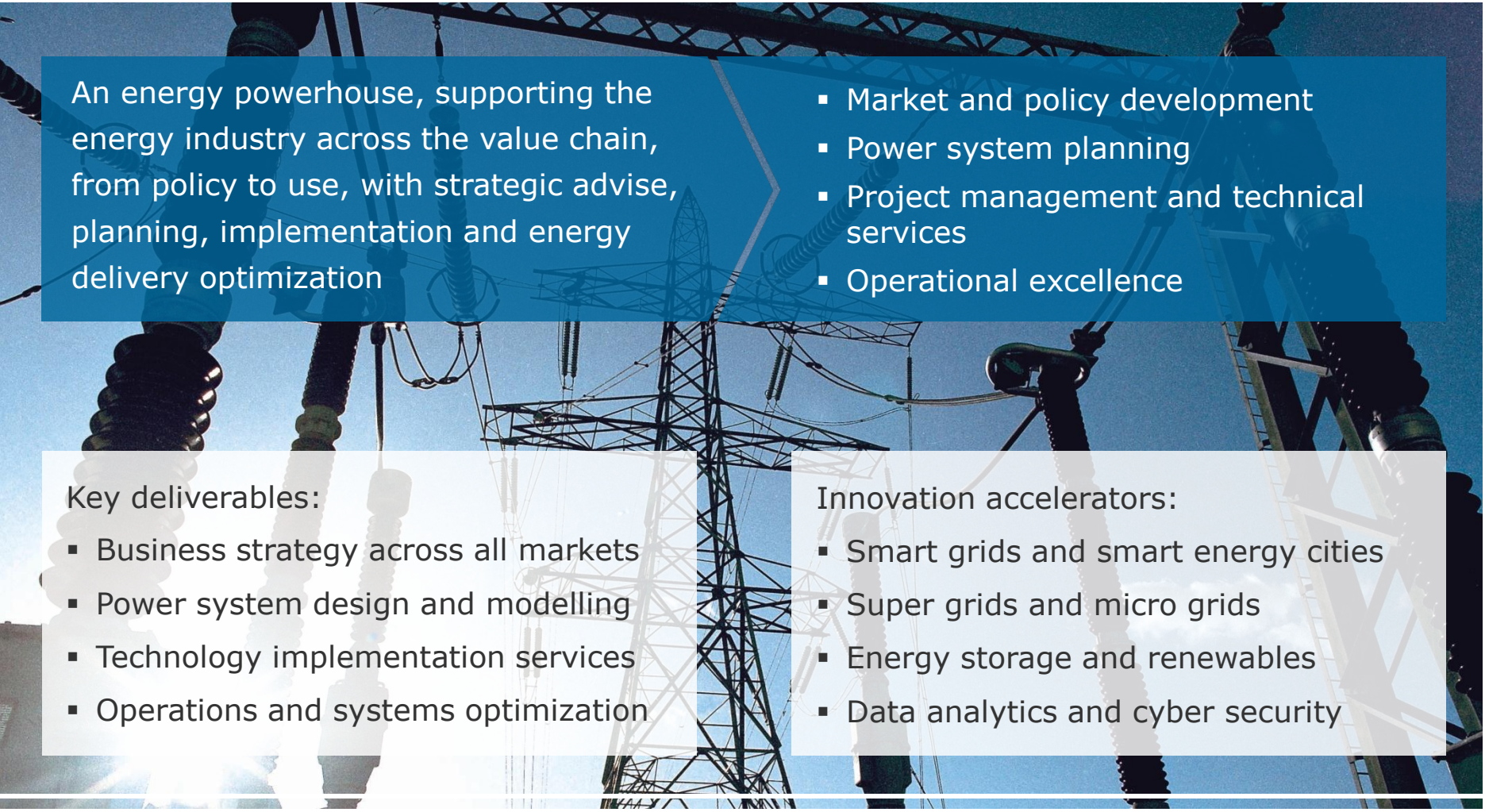
Industry consolidation

Energy advisory



An energy powerhouse, supporting the energy industry across the value chain, from policy to use, with strategic advise, planning, implementation and energy delivery optimization

- Market and policy development
- Power system planning
- Project management and technical services
- Operational excellence

Key deliverables:

- Business strategy across all markets
- Power system design and modelling
- Technology implementation services
- Operations and systems optimization

Innovation accelerators:

- Smart grids and smart energy cities
- Super grids and micro grids
- Energy storage and renewables
- Data analytics and cyber security

Content

- Biomass in South Africa
- Co-firing of biomass
- Full conversion of coal to biomass
- New build biomass
- Considerations & conclusions

Biomass in South Africa

Biomass in South Africa

- Biomass types available
  - Pine, wattle (acacia), eucalyptus
  - Stubs/stover (corn), bagasse
- Physical aspects
  - Logs, chunks, chips (moisture content 30-50%)
- Sample preparation according to
  - CEN 14780,
  - CEN 14418
  - NTA 8202
- Processing options
  - Densification (pellets or briquettes)
  - Thermally untreated (moisture content <10%)
  - Thermally treated (moisture content <5%)

Left-overs at Safcol plantations

Biomass co-firing

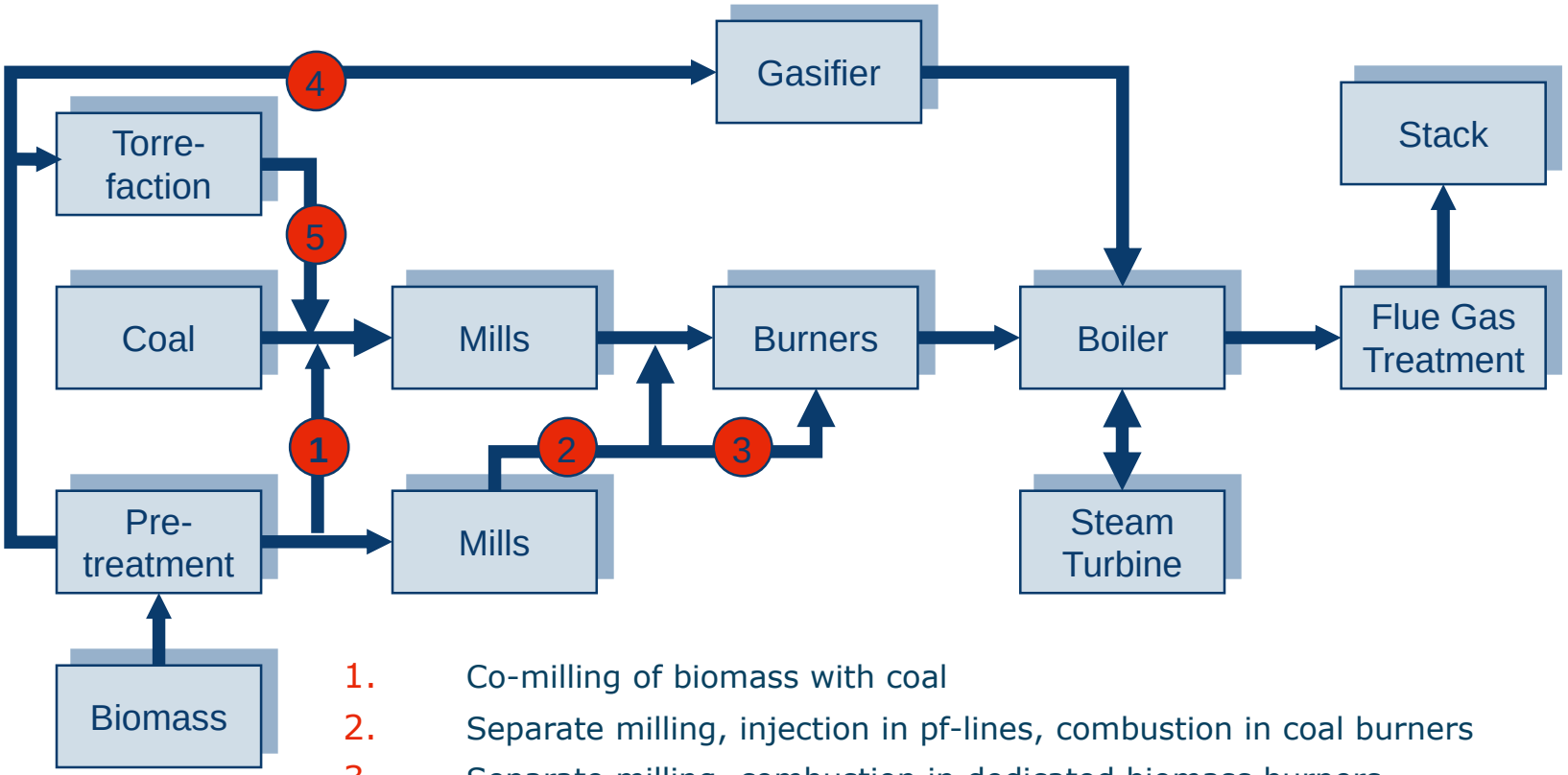
Co-firing of biomass – General status

Parameter	Unit	Range	Comments
Plant capacities	MW	Up to 600 MW	In existing power stations
Amount	%	Up to 40%	On a thermal base
Biomass type	-	Pellets	Primarily (traded) wood pellets
Regions	-	Europe, Korea	Countries with existing coal assets that have right policy measures

Traded industrial wood pellet cost from US to CIF ARA (Europe) 180-200 USD/tonne, based on contracting terms & conditions

(source: derived from Brodie Govan, Current developments and prospects for the interational pellet trade from a broker's perspective, Berlin, October 2014), typical clients include E.ON, GdF Suez, RWE, Drax

Co-firing of biomass - Routes



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

Each co-firing route has its own (unique) operational requirements and constraints and specific demands on the fuel quality

Co-firing of biomass - Some figures

Amer Power Station (Essent)

Logistic system storage capacity 20000 m3

Unloading capacity 600 kton/yr

Quay for 2 ships

<u>Co-firing in the Netherlands (2010)</u>

biomass consumption : 28,5 PJ

at 16 GJ/ton -> 1,8 mln tons

net generation : 3,2 mln MWh

this is around 420 kWh per household

<u>Co-firing experience at NL power stations</u>

Essent's Amer Centrale (2 units)

Electrabel's Centrale Gelderland

Nuon's Willem Alexander Centrale

E.ON's Centrale Maasvlakte (2 units)

EPZ's Centrale Borssele

Co-firing biomass – Physical infrastructure in PF stations

Storage
- Piling
- Bunkers

Logistics
- Conveyors
- Feeders
- Mills

Steam plant
- Burners
- Furnace section
- Convection section

Flue gas
- Flue gas cleaning system
- Stack

Source: DNV GL Image Library (Hemweg 8)

Co-firing biomass - Primary fuel types in PF stations

	Coal	Wood pellets	Torrefaction pellets	Steam explosion pellets
LHV (dry, MJ/kg)	23 - 28	16 - 18	20 - 24	17 - 19
Volatiles (% dry)	15 – 30	75 - 85	55 - 75	70 - 80
Bulk density (kg/m³)	800 - 850	500 - 650	550 - 850	700
Grindability	Good	Limited	Good	Good
Hydroscopic nature	Hydrophobic	Hydrophilic	Hydrophobic	Hydrophobic
Durability	Good	Good	Depends	Good
	Base fuel for existing stations	State-of-the-art co-firing fuel	Innovative fuels that have been applied in (co-)firing trials	

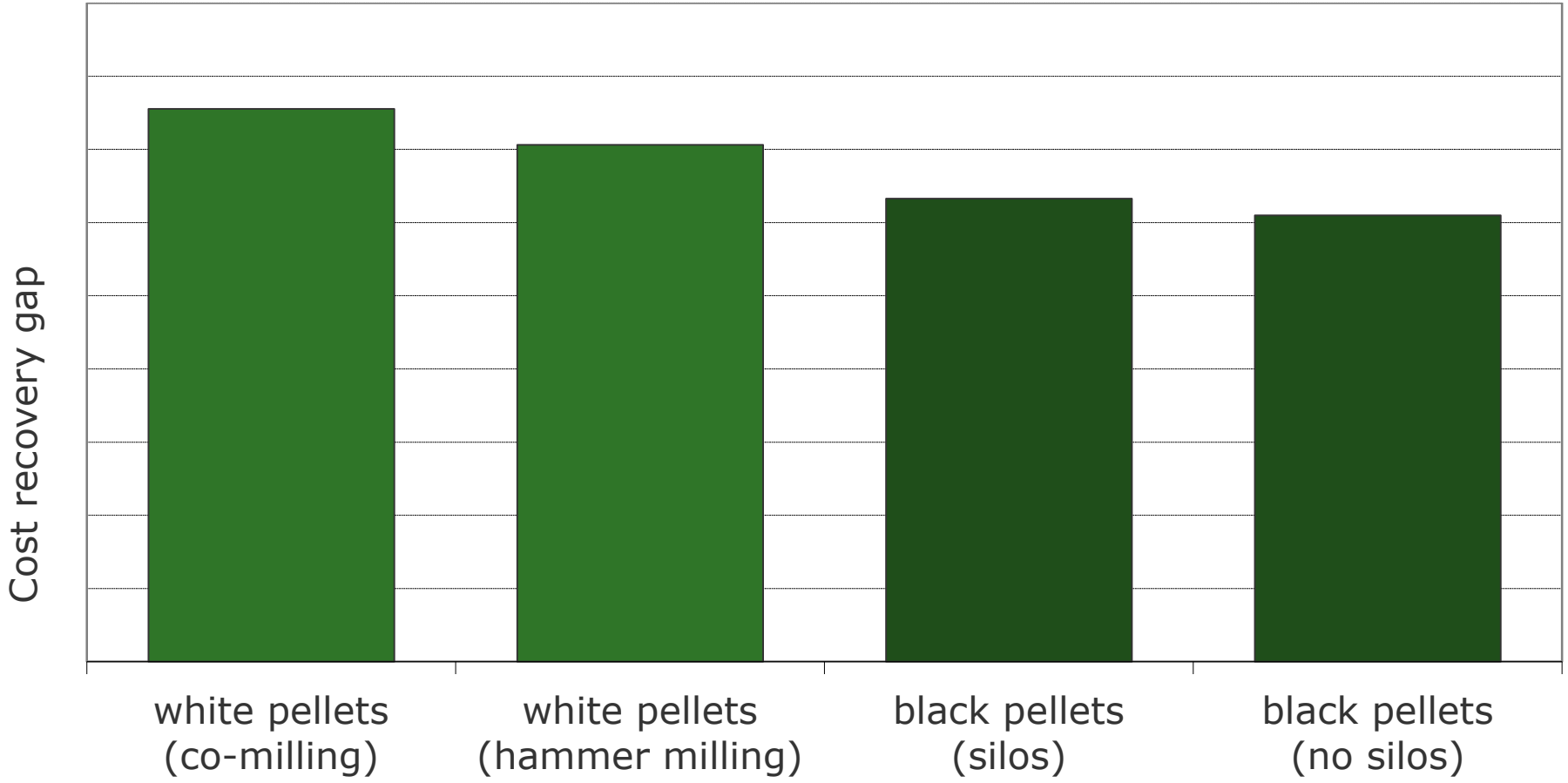
Co-firing biomass - Effect of fuel on plant operations

Fuel property	Main effect on	Potential unit impact
Bulk density	Conveyers, feeders and mills	Derate
Durability	Dust formation	HSE
Size and shape	Flow properties: conveyers and bunkers	Derate
LHV	Fuel flow	Derate
Moisture content	Fuel flow, drying capacity	Derate, efficiency
Composition	Specific air & flue gas volume, emissions	Efficiency, derate, ash, compliance
Grindability	Mill throughput	Derate, ash
Reactivity	Mill conditions	Derate
PSD after milling	Combustion, emissions	Efficiency, compliance
Volatile content	Combustion	Efficiency, derate
Ash properties	Slagging, fouling, abrasion	Efficiency, maintenance

Safety in storage and handling!

Co-firing of biomass – Levelized cost – Cost recovery gap

Coal to biomass cost recovery gap



Co-firing of biomass – Examples over the years

Some examples (all pulverized coal)

Plant	2008 [1)]	2014	Comment	-
Amer PS Unit 9 (600 MWe 350 MWth)	27% (pellets) + 5% (B-wood)	Currently none	Subsidy ended, possibly co-firing in future. Long-term co-firing of (mainly) white wood pellets. Gasification of demolition wood	 Source: RWE
Drax PS (4000 MW)	None, contract for biomass plant for 10% co-firing	80-100% (pellets) at 2 units	UK subsidy scheme favors full conversion. Announced expectations to have 3 (out of 6) units converted in 2015/2016	 Source: Wikipedia

1) KEMA, Co-firing high percentages – new chances for existing power stations, IEA Task 32 Workshop, Geertruidenberg, 2008

Conclusion: Policy measures have major influence on feasibility of biomass firing options

Coal to biomass conversion

Coal to biomass conversion – General status

Plant type	Pulverized fuel	CFB [1)]	BFB	Grate	Comments
New/existing	Existing	New	New	New	New is also retrofit option
Plant capacities	200 – 450 MW	150 – 550 MW [2)]	<100 MW	<75 MW [3)]	Electricity based, heat additional
Biomass type	Wood pellets	Biomass, peat, coal, oil, waste	Difficult fuels (litter, waste)	Coarse, low moisture, high LCV	-
Regions	Europe, Canada	World wide	World wide	World wide	-
Examples	Drax, Atikokan	Jyvaskylan, Połaniec	BMC Moerdijk, Cuijk	TWENCE	-

1) Often applied in multi-fuel (co-firing) mode

2) Possibly to 800 MW in the future

3) Higher in retrofitted PF coal plants

Coal to biomass conversion - Pulverized fuel – Atikokan GS

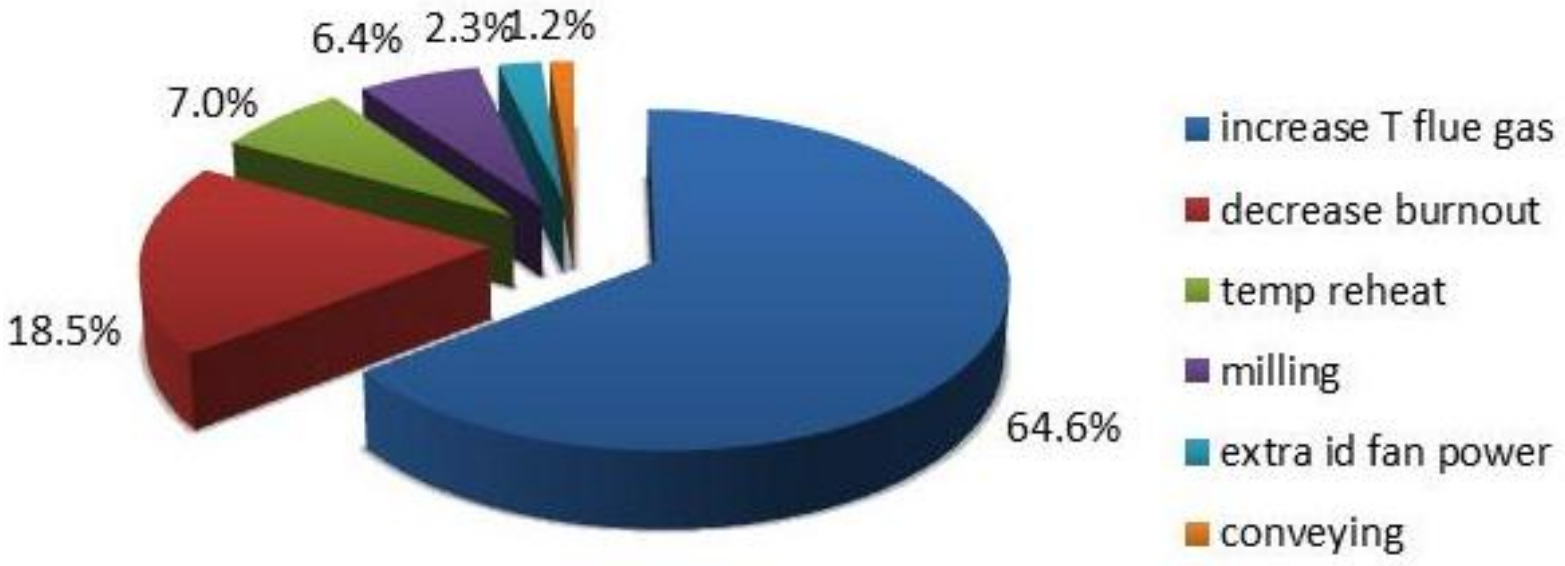
- Owner: Ontario Power Generation, Canada
- Capacity: 235 MW (gross)
- Fuel: Designed for lignite
  - conversion to wood pellets
- New fuel handling system + burners
- 2x5000 tons silo storage (90 full load hours)
- New truck receiver and transfer tower
- Mill conversion, Amer experience

Source: OPG

Conversion to biomass - efficiency loss (example, wood pellets)

Example:

Conversion to wood pellet firing; decrease in unit efficiency by 4.6% relative



Contributors to decrease in unit efficiency:

increase of flue gas temperature; decrease in live steam flow (due to low burnout); some increase of attemperation reheat flow

Conclusion: Wood pellets current option for large scale coal-to-biomass conversion, at cost

New build biomass

New build biomass - Circulating fluidized bed - Polaniec

- Owner: GdF Suez
- Capacity: 205 MWe
- Anticipated fuel:
  - Waste wood chips (80%)
  - Agricultural waste (20%)
- Corrosion resistant materials in boiler sections
- Foster Wheeler boiler island

Source: power-technology.com

New build biomass - Bubbling fluidized bed – BMC Moerdijk

- Partners: DEP, ZLTO, DELTA
- Capacity: 36 MWe (gross)
- AE&E boiler island
- Fuel: chicken litter (450.000 t/y)
  - 1/3rd of annual Dutch production
- Extensive flue gas cleaning
- Ash sale (mainly exported as pellets)
- Efficiency (gross) > 30%

Source: ZLTO

New build biomass - Grate – BEC TWENCE

- Owner: TWENCE waste incinerator
- Capacity: 20 MWe (net)
- Fuel: (low grade) waste wood
  - 140.000 tons per year, 73 MWth
- Standardkessel

Source: Standardkessel

Conclusion: New build biomass options (BFB, CFB, Grate) for (difficult) local fuel types

Considerations

Considerations

- Wood chips
  - Locally available and applied (transportation distance typically < 100 km)
  - Applied in Stoker, BFB, CFB (example: Twence)
  - Often in CHP mode
  - High investment cost (per kWe), low fuel cost (typically 30-60 EUR/t)
- Wood pellets
  - National and international trade
  - Applied in residential boilers, CHP boilers (furnace) often for heating
  - Also applied as state-of-the-art fuel for replacement of coal in PF plants (example: Drax)
  - Medium to low investment cost (per kWe), high fuel cost (residential 280-350 EUR/t, industrial international trade ~150 EUR/t)
- Torrefied fuel
  - Commodity market to be established (now: from demo-scale to full commercialization)
  - Both for co-firing as well as other specific applications
  - Currently co-firing trials (typically several thousands of tons per trial)
  - Low to no investment cost, high fuel cost (commercial price to be set)

Conclusions

Conclusion

- Wood pellets are the current state-of-the-art for biomass co-firing in pulverized fuel power stations
- Torrefied pellets technically ready for large scale commercial introduction. Named advantaged to be proven at a large scale now
- The choice for co-firing or conversion is mainly driven by policy measures
- New build installations
  - Wide range of (local) biomass types
  - Mainly BFB, CFB or grate, depending on feedstock
- Wood pellets for heating with low investment cases

Thank you for your attention

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