Biofuel and Biomass firing technologies
Brazil (project):
UTE: 3 x 12 MWe
3 x 160,000 t of wood

Czech Republic (cofiring):
Olomouc CHP: 41 MWe
Krnoc CHP: 6.3 MWe
50,000 t of wood

Germany:
Leinefelde CHP: 2.1 MWe
60,000 t of wood

Spain (project):
San pere: 6 MWe
65,000 t of wood

Chile (project):
Masisa CHP: 6.5 MWe
180,000 t of wood

Estonia:
5 heating plants
25 MW (th)
60,000 t of wood

Lithuania:
8 heating plants
100 MW (th)
250,000 t of wood

DALKIA’s experience: More than 600,000t of biomass p.a. (More than 80 plants)
Biomass as Fuel
Some examples of bio-fuels (2 main categories):
- Wood and waste from wood industry
  - Wood chips, Sawdust, Shavings, Barks, Pellets, Logs
  - Etc…
- Agricultural products and waste
  - Straw
  - Seeds
  - Hemp
  - Fast-growing trees (willows, poplars)
  - Grasses
  - Etc…
- Co-fired fuels:
  - Peat, coal, sludge, etc...
  - But also: Straw + wood, etc..

Significant variety and possible combination which generate for each of them their own technical challenge
The full chain of biomass

Fuel receiving/preparation/storage block diagram

- Straw
- Bark
- Sawdust
- Other wood
- Industry residue
- Forest exploitation residues
- Recycled wood
- Logs
- Rejected fuel

Fuel weighing / metering
Unloading
Checking

Long time storage
Natural drying

Metal removal
Crushing
Screening
Fuel mixing
Checking

Checking and analysis
Fuel weighing
or heat metering at boiler output

(3 to 7 days)

Represent transfer by automatic system (conveyor, screw, bell, etc) or by human action (loader, truck, etc)
Continuous availability of the primary energy.

One example: Straw

- Different kinds: Wheat, barley, rye, rape, etc..
  - Rape: High Calcium rate => Limited quantity (ash melting point)
- Yield per ha: 4.5 to 12 t/ha depending on kind.
  - Ratio grain/straw: 0.5 to 1.1 => Various straw yields
- Quantity availability: +/-5% depending on weather
- Logistics:
  - Distance of the resources (max 100km), roads, size of bales, density (100 to 300kg/m3), storage (short harvesting), loading lorries, access to field, etc..
- Other markets for the fuel

Critical to anticipate the variability of the resource and to have a local understanding of it
Additional information required about the primary energy

- Physical and chemical characteristics
  (Using representative samples):
  - CV range
    - Potential uneven combustion
  - Moisture (And CV)
    - Overweight fuel handling
    - Reduced boiler capacity (=> burn more expensive fuel)
    - Reduced efficiency
    - Excessive flue gas on flue gas treatment
  - Ash content
    - Overweight ash removal systems
    - Increased costs and wear
Additional information required about the primary energy

- Physical and chemical characteristics
  (Using representative samples):
  - Temperature of ash fusibility (K, P, Mg) and alkaline components (K, Na, Ca)
    - Bed /gate impact
    - Fouling impact
    - ESP impact
  - Impact of fertiliser, pesticides, salts (Cl, S)...
    - High temperature corrosion
    - Corrosion if low temperature feedwater/DHN water (<85C)

- Mechanical characteristics:
  - The upstream preparation condition
    - (Risk of stones (Screws..), metal, plastics (HCl),.., Uniformity, Seasonality, Storage,..))
  - Granulometry
    - (Max, min, average)

Solution: Improve the fuel quality with supplier
Storage (Long term and on site)

- Risk of fire (Regulations)
- Risk of fermentation (Methanisation)
  - Impact LCV and ash content
- Impact of rainfall and wind (dust)
- Undesirable elements (stones, plastics, metal parts,..)
- Quantity
- Tendency to freeze (due to the high moisture content)
- Design of storage (drain, ground quality, walls, fire protection,..)
- On site unloading/loading and boiler feeding:
  - Automatic or manual
- Mixing on long term storage (crane, loader, etc..)
- Etc…
Biofuel is stored in the plants in open or covered storages. Fuel amount is from 3 to 7 days plant operation.

**Vibrating bin storages** 2x40m³ with screw conveyors for 400 kW boilers

**Wood chips storage** 2000 m³ with rail-mounted grab and belt conveyor

**Straw storage** 300 tons

**Wood chip storage with moving floor**
Fuel handling

- Mixing capability on site (If various fuels, straw, moisture..)
- Ice protection
- Metal removal
- Screening
- Large element removal
- Crushing
- ATEX requirements
- Etc…
Technical recommendations:
- Oversize installations (Crusher (60% of MCR), conveyors (200% of MCR), etc.)
- Magnet
- Avoid elbows / steep slopes
- Size front silo for 30-60 min. of boiler operation on MCR (if BFB, CFB)
- Doors, stairs and platforms for maintenance and supervision.
- Etc..

Typical cause for unavailability:
- Screw damage => design, fuel quality, prefer chain conveyors
- Accelerated wear (Chute,..)=> fuel quality, design
- Chain conveyor feeding the boiler => light design, wet fuel
- Screw/conveyor for ash => foreign bodies, high ash content
- Vitrification => low ash melting point, high furnace temp.
- Etc.
Energy metering for the fuel

- Weight
- LCV
- Ash
  - (removed dry/wet, sand input- from bed or fuel, fly ash, bottom ash, etc…)
- Moisture content
  - (conductivity, sampling…)
- Size screening
- Undesirable element (Metal, ice, snow, stones, etc…)
- Etc..
- Can be difficult if:
  - **Mainly if fuel quality is inconsistent and/or various kind of fuels are used**
  - More than one supplier (depending on invoicing method)
  - Large plant meaning many samples
  - Method of invoicing (inlet/outlet boiler)?
Technologies and compatibility with Biomass
Classification of solid fuels: Biomass is a challenging fuel.
Challenging fuels

- **Too dusty fuel** (sawdust, straw, …)
  - Fouling in boiler-house and around fuel handling station; **ATEX** regulation;
  - Risk of fire and explosion (in boiler, ducts and flue gas treatment)
  - Incomplete combustion in the furnace (for grates) and of combustion in the second pass
  - colder bed if BFB, CFB

- **Too wet fuel**
  - Tendency to freeze, bridging
  - Overload in fuel receiving station, conveyors
  - Reduced boiler capacity (fuel volume limited, excessive flue gas temperature, need top up with expensive fuel..)
  - Reduced efficiency (Incomplete combustion with grate or spreader stocker if not homogenous)

- **Too dry fuel**
  - Hazard of overheatind and damaging grate
  - Ash melting /Vitrification:
    - Bed and refractory agglomeration
    - Sand agglomeration if BFB, CFB
  - Recirculation may be needed (to control the oxygen level and regulate the combustion –BFB)

- **Ash content**
  - Overload fuel removing system
  - Foreign bodies
Boiler sizing

- Must run for a minimum of 8000 hours a year
  - For economical reasons (high investment)
- Sized on summer needs (DHN) or base load for industry
  - Prefer CHP to condensation
  - Take into account technical minimum of other boiler(s)
  - Availability of the biomass resource
- Flexibility
  - No peak lopping or fast response time capability
  - High inertia (up to 30% for grate, spreader stoker boilers)
  - Time needed for start and stop depend on size and technology (esp. if sand bed)
- Minimum load
  - Depends on boiler size, technology and fuel. (Varies from 30 to 60%)
  - But Steam parameters may change below a certain point (e.g. 70%)
- Can be multi-fuel boiler
  - To secure the fuel supply
  - Fossil fuel needed for BFB /CFB
- Compatibility with fuel
  - The smaller boilers are adapted for higher fuel quality (dry wood logs, pellets, wood chips)
- Heat or power generation
Combustion technology

- Fixed or moving grate
- Spreader stoker
- Fluidised bed (BFB, CFB) (> 15/20MW)
- Cigar burners (10 /30 MW)
- Gasification.

Mix (examples):
- Straw with cigar + grate for wood (up to 100%)
- Straw for grate + spreader for wood (up to 50%)
- Sludge injection in chute of grate boiler
- Etc..
Combustion technology: Grate/ BFB - CFB / Cigar

- Moving/fixed grates
- Rotating grate with Volcan furnace
- Cigar burner and grate with straw disintegrator
### Combustion technologies

#### Comparison of existing systems

<table>
<thead>
<tr>
<th></th>
<th>BFB or CFB</th>
<th>Mobile grid Burner with placed feed</th>
<th>Spreader stoker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel flexibility</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Fuel granulometry</td>
<td>0</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Efficiency</td>
<td>++</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Auxiliary electrical consumption</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ash &amp; residues</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Reactives / Sand</td>
<td>+ / -</td>
<td>- / +</td>
<td>- / +</td>
</tr>
<tr>
<td>Emissions (CO / NOx)</td>
<td>- / +</td>
<td>0 / -</td>
<td>+ / 0</td>
</tr>
<tr>
<td>Load follow-up</td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Price</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Boilers 40-400 kW

Wood logs boilers
Upside down flame ("gasifier effect")

Mobile grate

Pellets or chips boilers

Under feed stoker
400 kWth biomass boiler-house

- Feed hopper
- Screw conveyor
- Multicyclone
- Gas extraction
- Screw feeder to boiler’s combustion chamber
- Flying ash collector
- Bottom ash removal
- Boiler
## Combustion technology: Size of boilers

<table>
<thead>
<tr>
<th>Range of use</th>
<th>Capacity</th>
<th>Type of boilers</th>
</tr>
</thead>
</table>
| Domestic boilers                          | 15-40 kW th  | • Thermal-fireplaces  
• Wood thermal-stoves  
• Wood boilers  
• Pellets boilers  
• Upside down flame (gasified effect) |
| Boilers for big houses                    | 40-400 kW th | • Upside down flame (gasified effect)  
• Fixed grate  
• Under feed stoker fireplace (hearth)  
• Pellets boilers |
| District heating boilers                  | 0.4 – 20 MW th | • Moving grate  
• Spreader stoker  
• Bubbling fluidised bed (>15MW)  
• Cigar (>10MW) |
| Industrial boilers for power and/or heat production | 1-80 MW th  | • Moving grate  
• Spreader stoker  
• Cigar (<30MW)  
• Bubbling fluidised bed (BFB)  
• Circulate fluidised bed (CFB)  
• Gasification |
| Industrial boilers for power and/or heat production | 80-300 MW th | • Bubbling fluidised bed (BFB)  
• Circulating fluidised bed (CFB) |
Efficiency depends on

- Load
- Boiler size
- Fuel (Moisture: +10% => About -1% efficiency)
- Technology and manufacturer
- Method of calculation (through fuel or losses)
- Scope (deaerator, blowdown, etc…)

Power consumption:
- For grate, spreader stokers technologies:
  15-25 kWe/MWth (pumps, FD, ID, ESP, fuel handling)
- For BFB, CFB technologies:
  25-35 kWe/MWth (air booster, flue gas recycling etc.
- NB: Traditional gas boiler house: About 10 kWe/MWth
**Heat and Power generation**

- **Hot water and process Steam**
  - Pressure depends on the application (DHN, etc..)
  - No specific problem with P&T

- **Steam parameters for power generation**
  - according to the turbine characteristics and the outlet levels for the customer process
  - To risk of fouling (ash melting point)
  - To risk of corrosion
  - Typical parameters:
    - Plant < 16 MWt P = 24-45 bara; T=350-440°C
    - Plant between **15 and 70 MW** P = 40/65 bara ; T = 420- 540 °C
    - Plant > 70 MW : P = 90 bara ; T : 540 °C
    - With Straw, parameters can reach 90bar/540C or 200bar/560C
  - CHP or condensation mode
  - Stability of parameters for ST

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Greenfield or retrofit?

- A retrofit can half the investment cost
  - Risk of the lifecycle of the remaining parts
  - Difficult interface with existing plant during construction
  - There may not be enough space
  - From coal or other boilers
  - Requires experienced boiler manufacturer

- A Greenfield
  - Guarantees latest technology for all plant
  - Dedicated plant
Fuel drying

- Drum dryer or Mat dryer
- Often quite problematic => Not recommended in general
  - Operational issues
  - Space required with flue gas temperature >170°C
  - Displace useful heat (>140°C required) if steam or hot water is used.
  - NB: Technologies in appendix
Availability

- **BFB or CFB:**
  - 8200 hours p.a.

- **Grate**
  - 8050 hours p.a

- **NB:**
  - Depends on reliability, easy access for maintenance,..
  - Reduced availability on the first year
  - 12 or 24 months availability guaranteed
Investment and O&M

- **Investment:**
  - Technologies
  - Steam parameters
  - Level of manning and automation
  - Turnkey or EPCM
  - Market (Appetite of suppliers, steel,..)

- **Operation**
  - Design and technologies

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Depends a lot on fuel, technology and contractual risk organisation

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Dalkia
Ash: A critical issue

- Typical ash content (On dry)
  - 3% wood, 8% bark, etc…
- Technologies:
  - Multi-cyclone (<4 MW),
  - ESP (except agriculture biomass),
  - bag filters (Risk: CaO + H2O).
- Ash from
  - Bottom ash, Second pass ash and fly ash
  - 70/30% depending on technology
  - 10% unburned
- Good design of ash removal systems is key for reliable operation
  - (hoppers, screws, cooling system, screening, Containers, silos)
- Prefer recycling to landfill
  - Classified as non-hazardous waste
  - But as waste….
  - Certification + (N+P2O5+K2O) <7% for fertilizer
- Cost issue
Conclusion: Biomass projects are good and worth doing with:

- “Local” source of fuel

- **Close partnership with supplier(s)**
  - good understanding of the fuel supply chain for design and operation

- **Appropriateness of fuel/technology:**
  - Biomass is not “exact science” nor perfect
    - (stones, metal, CV, ash, moisture,…)
  - Design based on good knowledge of the *real* fuel quality
  - Success can be ensured by operationally *experienced* parties for the design and the operation of a plant using:
    - technologies and design of plant which are reliable, mature and easy to O&M
    - compatible with the fuel
    - compatible with the energy demand