Workshop on

Fuel Flexibility in Biomass Combustion
The Key to Low Bioenergy Costs?

Arranged by:
Claes Tullin, SP, Sweden
Jaap Koppejan, TNO Science and Industry, Netherlands

World Bioenergy 2006 Conference
Jönköping, Sweden
May 31, 2006

Task 32: Biomass Combustion and Cofiring
IEA Bioenergy Task 32
Fuel Flexibility in Biomass Combustion
May 31, 2006, Jönköping, Sweden

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## Programme

31 May 2006, 14:00-18:00  
World Bioenergy 2006 Conference, ELMIA conference centre, Jönköping, Sweden

<table>
<thead>
<tr>
<th>From</th>
<th>Topic</th>
</tr>
</thead>
</table>
| 14:00 | Opening  
Sjaak van Loo, IEA Bioenergy Task 32                                |
|       | **Part A: Market issues**                                             |
| 14:10 | “Future Supply of Biomass for Fuel; Sources, Quantities and Costs”    
Bo Hektor, Talloil                                                  |
| 14:30 | “Availability of biomass and biomass supply systems for co-firing purposes” 
Martin Junginger, Utrecht University                               |
|       | **Part B: Fuel characterisation and standardisation**                 |
| 14:50 | “Is representative and relevant composition data for heterogeneous solid  
recovered fuels possible to accomplish?”                             
Evaluation Wikström, SP                                              |
| 15:10 | “BioNorm – A project to support the ongoing standardisation process”   
Jan Burvall, SLU                                                     |
|       | **Part C: Fuel preparation**                                          |
| 15:30 | “Preparation of fuels based on waste material”                         
Sture Mattsson, IQR                                                  |
| 15:50 | Coffee Break/Refreshments                                             |
|       | **Part D: Fuel quality and deposit formation/emissions**              |
| 16:20 | “Deposit formation during combustion of different waste wood qualities and  
co-combustion of waste wood and sewage sludge”                        
David Eskilsson, SP                                                  |
| 16:40 | "Experience from waste co-combustion in Vattenfalls fluidized bed boilers" 
Matts Almark, Vattenfall                                             |
|       | **Part E: Boiler design**                                              |
| 17:00 | “Fuel flexibility through (co-)firing biomass in Belgian pulverised coal  
power plants”                                                      
Yves Ryckmans, Electrabel                                           |
| 17:20 | "Wet bio-fuels-Aspects on furnace design and boiler operation"         
Niklas Berge, TPS                                                   |
| 17:40 | Discussion and conclusions                                            
Claes Tullin, SP                                                    |
| 18:00 | Closing                                                               |
The use of biomass for energy generation is predicted to increase very much supported by both economical, ecological and political drivers. This development will cause changes in the fuel structure which in turn will put demand on combustion technology to cope with new and “difficult” fuels. The present range of fuels consists mainly of residues from the forest and agriculture sectors and from waste. As long as the supply of biomass has been in abundance the cheapest and least problematic fuels have been utilized. In the future, more of residues and wastes will be in demand, but the principal increase will probably be in form of biomass from dedicated plantations, e.g. energy crops and fast growing tree plantations. The biomass potential has been estimated (IEA Task 40) to between 250 and 500 EJ (90 000 - 180 000 TWh) with very large potentials in tropical regions, thus indicating an opportunity for development of poorer regions. However, in the development of large scale bioenergy plantations utmost care must be taken in considering social structures as well as ecological problems.

Global trading of biomass fuels is quite possible provided that ocean ships can be used for the longer distances. As an example, at a cost of 20 € per ton, the number of transport kilometers by ship is about 10 000 km. This can be compared with 200 km by lorry or 600 km by railway. With transportation not being a barrier, tropical countries can be major suppliers of biomass fuels on the global market within 15-25 years time. As transportation is a major factor influencing fuel cost and the fuel energy balance, it is often advantageous to upgrade the fuel to obtain a higher energy density. There are a large number of possible biotrade chains depending on available biomass fuels, different degree of refining and upgrading, means of transportation and conversion and end use. Development of sustainability criteria for biomass (likely including CO2/energy balance, food security and nature & biodiversity criteria) requires new efficient biomass supply chains.

With an increased availability of waste fuels as well as new energy crops on the market, proper fuel analysis are needed as correct fuel composition data has a large impact on the accessibility, emissions and maintenance cost of a boiler. In order to meet the requirements of relevant standards the EU-project BioNorm was initiated. In the project, the limitations of existing analysis procedures have been highlighted and improved sampling and testing procedures has been developed. The work has been closely linked to the work in CEN C 335 “Solid Biofuels”. A major problem that needs further work is how to obtain representative samples of heterogeneous fuels without the need to handle large sample quantities.

Cheaper fuels often means increased costs for operation and maintenance, often due to increased deposit formation and corrosion on boiler walls and superheaters. Waste wood, for instance, contains higher amounts of the deposit related compounds such as zinc, lead and chlorine. By choosing optimal fuel combinations, it is possible to reduce the problems of deposit formation radically. By co-combustion of sludge and waste wood, the deposit formation has been shown to decrease dramatically. Secondary measures to reduce problems include the ChlorOut process where the alkali chlorides are measured on line and controlling the amount of a sulphur containing compound that is introduced into the boiler. The sulphur reacts with the metal chlorides forming more stable, and non-sticky- sulphates. As a spin-off, the sulphur addition can also result in lower CO and NOx emissions. Similar effects can be obtained by co-firing a sulphur containing fuel such as coal or peat. Other issues of importance when combusting biomass fuels with waste fuels in BFBC’s is to arrange a proper fuel feeding and removal of non-combustibles in the bottom bed. To achieve good fuel flexibility in biomass fired grate boilers it is necessary to have good control of the temperature in both primary and secondary combustion zones and control of the aerodynamics of the freeboard combustion. Key parameters are for instance air supply, flue gas recirculation, ash burn out. Co-firing (i.e. co-combustion of, generally smaller, fractions of biomass with coal), has been shown to be an
interesting way to develop bioenergy markets and to introduce bioenergy in large scale at high efficiencies. A number of installations are now in operation based on different technologies. A general problem with biomass (compared to coal) is that the volumes that must be handled are very large. This puts special requirements on logistics and organisation. Finally, for all combustion technologies, proper fuel pre-treatment is a prerequisite to obtain optimal combustion performance.

In conclusion, the present global introduction of bioenergy as one of the major renewable sources results in steadily increasing prices of biomass. The large variety of fuels and changes in availability with time results in large price differences. Thus, increased fuel flexibility is a possibility to reduce the fuel costs though care must be taken to control the operating and maintenance costs for instance caused by super heater corrosion. Recent developments in dedicated biomass combustion give insight as how to minimise these types of problems. An extensive experience regarding combustion of all sorts of biomass fuels is accumulating in biomass boiler applications as well as in co-firing applications. However, research is still needed to increase fuel flexibility and reduce the operating and maintenance costs. Not least important here are tools for fuel characterisation.

In order to cope with the new fuels that will be introduced on the market, a dialogue between the different stake holders in the biomass chain (from biomass and fuel production to final heat and power production and utilization of the residues) is needed. Activities that bring different stake holders together should be encouraged to develop integrated and flexible energy systems. A general problem that remains includes the development of an economically and ecologically sustainable large-scale bioenergy market.
Annex 1. Opening
Sjaak van Loo
Fuel Flexibility in Biomass Combustion
The Key to Low Bioenergy Costs?

Sjaak van Loo
Claes Tullin

World Bioenergy Conference Workshop
Jönköping, Sweden, 31 May 2006

Introduction to IEA Bioenergy (1)

• The **IEA** was founded to implement an international energy programme in response to the oil shocks.

• Activities are directed towards collective energy policy objectives of **energy security**, economic and social development, and environmental protection.

• Activities are set up under Implementing Agreements. There are **40 active Implementing Agreements**.
Introduction to IEA Bioenergy (2)

- IEA Bioenergy provides an umbrella organization where experts from research, government and industry work together

IEA Bioenergy Task 32: Biomass Combustion and Co-firing (1)

Objectives:

- To stimulate further expansion of the production of energy from biomass combustion

- Generating and disseminating information on technical and non-technical barriers and anticipated solutions for:
  - dedicated biomass combustion systems, and;
  - biomass co-firing in existing coal fired power plants.
IEA Bioenergy Task 32: Biomass Combustion and Co-firing (2)

- Experts from 12 countries:
  - Australia
  - Austria
  - Belgium
  - Canada
  - Denmark
  - European Commission
  - Germany
  - Netherlands
  - Norway
  - Sweden
  - Switzerland
  - United Kingdom

- Working together in:
  - Cooperative projects
  - Meetings, Workshops, Conferences, Excursions
  - Cooperation with other Networks

www.ieabcc.nl

Fuel Flexibility: The key to low bioenergy costs?

- The desire to cut costs leads to the use of “uncommon” and “low spec” biomass fuels

- Determining factors for optimal fuel-technology combination:
  - market issues
  - fuel characterisation and standardisation
  - fuel preparation
  - fuel quality and deposit formation/emissions
  - boiler design

- We wish you a pleasant and informative Workshop!!
Annex 2. Future Supply of Biomass for Fuel; Sources, Quantities and Costs
Bo Hektor
Future Supply of Biomass for Energy:
Sources, Quantities and Costs

Bo Hektor, TallOil AB, Sweden
May 31, 2006

Global biomass potentials are large - but need to be developed

Agricultural land: <100- >300 EJ
Marginal lands: <60- 150 EJ
Agri residues: 15-70 EJ
Forest residues: <30-150 EJ
Dung: 5-55 EJ
Organic waste: 5 - >50 EJ

TOTAL: < 250 - > 500 EJ

From IEA Bioenergy Task 40

500 EJ ~ 180 000 TWh
Sweden 625 TWh

<table>
<thead>
<tr>
<th>Region</th>
<th>Agricultural Land</th>
<th>Marginal Lands</th>
<th>Agri Residues</th>
<th>Forest Residues</th>
<th>Dung</th>
<th>Organic Waste</th>
<th>TOTAL</th>
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<td>Caribbean &amp; Latin America</td>
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<td>Sub-Saharan Africa</td>
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<td>East Asia</td>
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</tr>
</tbody>
</table>

From IEA Bioenergy Task 40

500 EJ ~ 180 000 TWh
Sweden 625 TWh
Agricultural land (1)

• Dedicated Energy Plantations
  – Single Purpose Plantations
    • Eucalyptus
    • Acacia (N-fixing species)
    • Salix
  – Multiple Purposes
    • Sugar cane
    • Sweet sorghum
    • Jatropha

Agricultural Land (2)

• Agroforestry
  – Shifting fallow
  – Shelter belts
  – Shelter trees
Marginal Lands

- Former forest land
- Depleted agricultural land
- Arid land

Can produce biomass + environmental values e.g. soil conservation/improvement, erosion control, flood control
Agricultural residues

- Straw
- Palm oil kernels, etc
- Olive kernels, etc.
- Rice husks, etc.
- Oil seed shells, etc.
- Pruning residues
- and a wide range of others

Organic waste and Dung

- (not covered in this presentation)
**Transport Costs**
*(general example)*

- **Lorry** 200 km € 20/ton
- **Rail-way** 600 km € 20/ton
- **Ocean ship** 10 000 km € 20/ton

**Prediction**

- Therefore,
  - Biomass fuels will be traded in a global market
  - Tropical countries will (within 15-25 years time) be the dominant large scale suppliers of biomass fuels in the markets; also local markets will co-exist where conditions permit
  - A wide range of biomass fuels will become available in the market.
Winners

- Those, who can integrate efficient combustion technology with acquisition of cheap, reliable fuels.
- Those, who can master system analyses and implementation of integrated solutions (business/technology)

Wood versus Oil
Principal Calculation

- 1 barrel oil (70 $) 6,12 GJ
- 1 ton wood substance (odt) 17 GJ
- 0,47 ton wood(+bark)substance = 1 m3s
- 1 m3s(+bark) 8 GJ
- 1 m3s/1 barrel oil 1.3

- Energy value of 1m3s 91 $
- Price of pulp wood 1m3s 34 $
Thanks for your Attention!

Bo Hektor       bo.hektor@talloil.se
Annex 3. Availability of biomass and biomass supply systems for co-firing purposes
Martin Junginger
Availability of biomass and biomass supply systems for co-firing purposes


Martin Junginger & André Faaij
Copernicus Institute - Utrecht University

Overview

2. Future supply chains – resources and pretreatment technologies (for biomass co-firing)
3. Some work of IEA bioenergy Task 40
Domestic renewable electricity production in the Netherlands

From <1% in 1995 to almost 50% of renewable electricity production in 2005

Co-firing of solid and liquid biomass in Essent power plants

Source: P.P. Schouwenberg, Essent Sustainable Energy
Imported fuels used:

- Wood pellets (mainly from Canada)
- Agro-residues (palm kernel shells, olive nuts, nut shells, cocoa husks, soy and sunflower residues)
- Palm Oil (Malaysia and Indonesia)
- Bone Meal and other waste streams
Current (policy) trends

- Palm oil deemed unsustainable, feed-in tariff cut from 7 €ct/kWh to <3 €ct/kWh
- Pellet market very volatile, present shortage of pellets
- Development of sustainability criteria for biomass, likely including CO2/energy balance, food security and nature & biodiversity criteria

=> New efficient & sustainable biomass supply chains needed

Global potentials are large...; but need to be developed

Agricultural land: <100- >300 EJ
Marginal lands: <60-150 EJ
Agri residues: 15-70 EJ
Forest residues: <30-150 EJ
Dung: 5-55 EJ
Organic waste: 5 - >50 EJ
TOTAL: < 250 - > 500 EJ
International bio-energy logistics not a showstopper when organized rightly

Logistic concept for production regions

Radius is average transport distance field farmer – unit
Based on ½ area
Field farmers are spread in area

Required area in km²:
Based on:
1. Field coverage
2. Biomass distribution density
Unit X requires certain biomass input “A”
Many possible ‘biotrade chains’

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Transport/transfer/storage</th>
<th>Importer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass production</td>
<td>‘raw’ biomass</td>
<td>Full conversion</td>
</tr>
<tr>
<td>Biomass production &amp; pre-treatment</td>
<td>Pre-treated (pellets, bales, bio-oil) biomass</td>
<td>(partial) conversion</td>
</tr>
<tr>
<td>Biomass production &amp; conversion</td>
<td>Fuels (H2, MeOH, EtOH, HC’s)</td>
<td>End-use conversion</td>
</tr>
<tr>
<td>Production and conversion</td>
<td>Electricity transport</td>
<td>End-use electricity</td>
</tr>
<tr>
<td>Biomass production</td>
<td>‘conversion along the way’</td>
<td>End-use</td>
</tr>
</tbody>
</table>

Source: Hamelinck, Faaij, 2003

Composing chains...

Legend:
- Harvest or collection
- Transport per truck (bulky)
- Transport per train
- Transport per ship
- Storage of liquids
- Conversion
- Electricity
- Pyrolysis oil
- Methanol

Source: Hamelinck, Faaij, 2003
Primary energy use of biomass supply chains to a Dutch power plant

Cost breakdown of solid biomass delivered to the Netherlands
Some key findings…

- Reference systems importing & exporting country crucial for net GHG impact.
- Economies of scale are crucial.
- Pre-treated biomass or secondary energy carriers preferred for international transport.
- Sea transport limited impact; road transport significant.
- Region specific (biomass distribution density, transport parameters, etc.).
Mozambique...

Batidzirai & Faaij, 2005

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**Level of advancement of agricultural technology**

<table>
<thead>
<tr>
<th>Level of agricultural technology</th>
<th>Water supply</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>rain-fed</td>
<td>No use of fertilizers, pesticides or improved seeds or breeds, specialised health care for animals and calf rearing activities, equivalent to subsistence farming as in rural parts of e.g. Africa and Asia.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>rain-fed</td>
<td>Some use of fertilizers, pesticides, improved seeds or breeds, animal health care and mechanical tools.</td>
</tr>
<tr>
<td>High</td>
<td>rain-fed</td>
<td>Full use of all required inputs and management practices as in advanced commercial farming presently found in the USA and EU.</td>
</tr>
<tr>
<td>Very high</td>
<td>rain-fed</td>
<td>Use of a high level of technology on very suitable and suitable soils, medium level of technology on moderately suitable areas and low level on moderately and marginally suitable areas.</td>
</tr>
<tr>
<td>Very high</td>
<td>rain-fed/irrigated</td>
<td>Same as a very high input system, but including the impact on irrigation on yields and areas suitable for crop production.</td>
</tr>
</tbody>
</table>
Potential surplus agricultural land in 2015 in Mozambique, dependent on the level of advancement of agricultural technology

Regional biomass annual production potential in Mozambique/PJ$_{HHV}$ (2015)

Batidzirai & Faaij, 2005
Comparison of bioenergy growing costs by region type (€/GJ)

Batidzirai & Faaij, 2005

Logistics for export....

Batidzirai & Faaij, 2005
Chains supplying pyrolysis oil from Mozambique to Rotterdam

Batidzirai & Faaij, 2005

Comparison of Torrefaction, pellets and Pyrolysis pretreatment

Uslu & Faaij, 2006
Comparison of co-firing wood pellets, torrefied pellets (TOP) and Pyrolysis oil

Cost of chains delivering electricity (co-firing)

- TOP co-firing
- Pellet co-firing
- Pyro co-firing

Energy use (GJ/GJ): 8.5% 11% 8%

Uslu & Faaij, 2006

Relevant work of IEA bioenergy Task 40

Country reports
- on Brasil, Finland, the Netherlands, Norway…
- Updated country reports and synthesis report to be published in autumn 2006

Market studies:
- on ethanol (published)
- on global wood pellet markets and resources (to be published end of 2006)
- On pyrolysis oil (to be published end of 2006)

=> Keep an eye on www.bioenergytrade.org
Thank you for your attention!

Refs to the studies presented:


Faaij and Uslu, Pretreatment technologies and their effects on international bioenergy supply chain logistics, Techno-economic evaluation of torrefaction, fast pyrolysis and pelletisation. Forthcoming.

Available at [www.chem.uu.nl/nws](http://www.chem.uu.nl/nws) -> publications
Annex 4. Is representative and relevant composition data for heterogeneous solid recovered fuels possible to accomplish?
Evalena Wikström
Sampling and preparation of heterogeneous waste fuels?

Is it possible to accomplish a representative and relevant composition data?

Evalena Wikström, Lennart Gustavsson and Jolanta Franke

Aim of the project

To suggest a method for sampling and mass-reduction valid for heterogeneous waste fuels

Consisting of:
✓ a minimal sample size that accomplish representative data
✓ a mass-reduction technique at site
✓ a routine for the first grinding step
✓ a sample reduction method at the lab
Background

- Two new standards “methods for sampling” and “laboratory preparation” for Solid Recovered Fuels (SRF) valid from ’06
- Heterogeneous waste fuels are about the most difficult to sample correct
- The composition varies a lot
- Correct fuel composition data has a large impact on the accessibility, emissions and maintenance cost of a boiler
- The future market of waste fuels will demand accurate composition data of a mixture

Example variation in data N=6

A 20 W Waste incinerator
Pre-treated, grinded waste
Example variation in data N=14

A 20 W Waste incinerator
Non-treated waste

Variation in sorting analyses

Wood
Paper, plastic
Textile
Biological
Element and risks

- Sampling
  - Method
  - Volume/mass
  - Duration time
- Sample reduction
  - Method
  - Volume/mass
- Preparation at the lab
  - Sample reduction
  - Size reduction
- Analyses
  - Method
  - Technique

Two new standards for Solid Recovered Fuels

Solid Recovered Fuels – Methods for sampling CEN 15442 (Jan 2006)

Solid Recovered Fuels – Methods for laboratory sample preparation CEN 15443 (Jan 2006)

What is required to work according to these standards
Two new standards for Solid Recovered Fuels

Necessary elements for developing a sampling plan

1. Define overall objectives
2. Define lot and determine lot size
3. Define sampling procedures
4. Define minimum number of increments
5. Define minimum sample size
6. Define effective increments and sample size
7. Define methods for reducing the sample size
8. Define analytical methods

Solid Recovered Fuels – Methods for sampling

Determination of minimum sample size

**Input/information required:**

- The nominal top size of a particle \( d_{95} \) = ?
- The maximum volume of a particle \( V_{95} \) = ?
- The shape factor \( s = V_{95}/(d_{95})^3 \) = ? or 1
- The particle density = 1
- The bulk density = ?
- The distribution factor = 0,25
- The factor \( p \) = 0,01
- The coefficient of variation \( CV \) = 0,01

=> minimum sample size
Solid Recovered Fuels – Methods for sampling

Determination of minimum increment size

Mechanical sampling

- The nominal top size of a particle $d_{95}$
- Drop speed

or

Manual sampling

- Drop speed
- Sampling time

=> minimum increment size

---

### Minimum sample size

<table>
<thead>
<tr>
<th>Nominal top size (cm)</th>
<th>Waste A</th>
<th>Waste B</th>
<th>Waste C</th>
<th>Waste s=1</th>
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<td>40000</td>
</tr>
<tr>
<td>50</td>
<td>50000</td>
<td>50000</td>
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</tr>
<tr>
<td>60</td>
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<tr>
<td>70</td>
<td>70000</td>
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<tr>
<td>80</td>
<td>80000</td>
<td>80000</td>
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</tr>
<tr>
<td>100</td>
<td>100000</td>
<td>100000</td>
<td>100000</td>
<td>100000</td>
</tr>
</tbody>
</table>

---

![Diagram showing minimum sample size vs. nominal top size]
Solid Recovered Fuels – Methods for sampling

- Effective increment size = Min sample size / #increments
  \[\Rightarrow \text{Effective increment size} > \text{Min increment size}\]

- Effective sample size = Eff. Increment * #increments
  \[\Rightarrow \text{Effective sample size} > \text{Min sample size}\]

#increments ≥ 24

Example:
When d95 is smaller than 30 cm the effective increment size and sample size is controlled by the waste flow to the incinerator.
Minimum sample size vs effective sample size

Sample reduction – reduce the size with unchanged sample composition

At the site: Coning, Strip mixing, Long pile, Manual increment division

At the lab: Riffle boxes, Rotary sample dividers, grinding

The third-power law controls the mass-reduction

<table>
<thead>
<tr>
<th>Reduction factor $d_{50}$</th>
<th>Reduction factor of the sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>10</td>
<td>1 000</td>
</tr>
<tr>
<td>30</td>
<td>27 000</td>
</tr>
</tbody>
</table>
Test plan of the project

- **Overall objectives:** To determine the possibilities to simplify the sampling methods and still accomplish a representative sample from a MSW incineration plant with non-treated waste
- **Define the lot:** 24 hours
- **Sampling procedure:** Manual, drop flow
- **Minimum number of increments:** 24
- **Minimum sample size:** \( d_{95}=30 \Rightarrow 400 \text{ kg} \)
- **Minimum increment size:** 37 kg (based on 22 ton/h)
- **Effective increment size:** 17 kg (400 kg/24)
- **Effective increment size > minimum increment size**
- **Effective sample size:** 880 kg (37*24)

Test plan

- Sample A ~ to standard
- Sample B = 100 kg
- Sample C = 10 kg
- Test of 25 and 50 % of the sample volume

- How well does sample B and C imitate sample A?
- What simplifications can be made without influence the quality?
- Which sample size is recommended?
- How much dose the initial preparation sample volume affects the quality of the data?
Test plan of the project

- A ~ Standard
- B = 100 kg
- C = 10 kg

A simplified sampling and preparation method

- Suggest a minimal sample size that accomplish representative composition data
- Suggest a mass-reduction technique at site
- Suggest a routine for the first grinding step
- Suggest a sample reduction method at the lab
- Based on experimental data and the two standards

…all valid and suitable for heterogeneous waste fuels
Annex 5. Bionorm – A project to support the ongoing European standardisation process of solid biofuels
Jan Burvall
Unit of Biomass Technology and Chemistry, Umeå

Jan Burvall

- Bioenergy, the whole chain from energycrop – heat water production
- Research on pellet production
- Characterisation of biomass focused on On-line technology e.g. NIR
BioNorm – A project to support the ongoing standardisation process

“Pre-normative work on sampling and testing of solid biofuels for the development of quality assurance systems”

EU Political Targets

- Reduction of greenhouse gases emissions by 8%
- White paper on Renewable Sources of Energy
- Renewable Electricity Directive
- European Biofuel Directive

Measures to achieve targets

- Definition of acceptable standards for classification, sampling and testing of solid biofuels
- Development and implementation of QM systems for solid biofuels
- Elimination of trade barriers by harmonisation of the existing rules within Europe
- Development of a European market for solid biofuels
Aim of Bionorm

To carry out pre-normative work on solid biofuels in cooperation with CEN TC 335 “Solid Biofuels” in the field of:

- Sampling and sample reduction
- Physical and mechanical test methods
- Chemical tests
- QA systems
- Integration of new EU-member States (NMS) and newly Associated States (NAS), respectively, in the standardisation process

Examples why BioNorm was needed for European standards

- CEN TC 335 Solid biofuels started in 1997
- Different methods for testing of solid biofuels were used within the European countries in many cases built on coal standards
- Round round robin tests showed a significant bias between some of them e.g. the ash content and durability for pellets
**Ash content**

Temperature at 550 °C or 815 °C

**Durability - pellets**

<table>
<thead>
<tr>
<th>ASTM</th>
<th>SS</th>
<th>ÖNorm</th>
</tr>
</thead>
</table>

![Images of equipment]
Durability - pellets

Yellow lines = SS 18 71 80                  Increasing diameter
Red lines = Lignotester O60
Blue lines = ASAE 269.4

Bionorm Structure

Fuel Quality Assurance WP IV

Sampling And Sample Reduction WPI
Physical and Mechanical Tests WPII
Chemical Tests WPIII

Research Ex-change With NAS
Bionorm

Project co-ordination

IE Institute for Energy and Environmental GmbH, Leipzig, Germany

Prof. Dr.Ing. Martin Kaltschmitt

Overview Data

- Project runs from Jan 2002 to Dec 2004
- 33 partners from 14 European Countries and 16 sub contractors involved
- 6 partners from NMS/NAS are active in WP VI (Bulgaria, Czech Republic, Latvia, Lithuania, Poland, Hungary)
- Total Budget: 5.7 Mio €
- EC contribution: 3.3 Mio €
- The project has been designed to support the of CEN TC 335 “Solid Biofuels”
European standards for Solid Biofuels CEN TC335

- Terminology
- Quality assurance
- Fuel specification and classes
- Sampling and sample reduction
- Physical methods
- Chemical methods

Today totally 28 Technical Specifications are published

Technical Specification and Standard – What is the difference?
WP I
Sampling and Sample reduction

• Task I.1 Investigation of methods for sampling biofuels

• Task I.2 Investigation of methods for sample reduction of biofuels

WP II
Physical and Mechanical tests

• Task II.1 Moisture content and bulk density

• Task II.2 Ash melting behaviour

• Task II.3 Particle size distribution

• Task II.4 Durability and raw density of pellets and briquettes
WP III

- Task III.1. Determination of sulphur, chlorine and nitrogen
- Task III.2 Determination of major and minor elements

Sampling - Biofuels

- Sampling
- Sampling from lorries
- Sampling plan and certificates
Biofuels – Sample preparation

Moisture content

- Reference method
- Simplified procedure
- General analysis sample
Losses of VOC when drying at 105 °C

<table>
<thead>
<tr>
<th>Calorific value for VOC in biomass</th>
<th>VOC as % of dry matter</th>
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</thead>
<tbody>
<tr>
<td>kJ/g</td>
<td></td>
</tr>
<tr>
<td><strong>α – pinene</strong></td>
<td>45.2</td>
</tr>
<tr>
<td><strong>β – pinene</strong></td>
<td>45.0</td>
</tr>
<tr>
<td>Carene</td>
<td>39.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biomass material</th>
<th>VOC as % of dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birch bark</td>
<td>0.30</td>
</tr>
<tr>
<td>Birch chips</td>
<td>0.04</td>
</tr>
<tr>
<td>Cork</td>
<td>0.05</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>0.03</td>
</tr>
<tr>
<td>Hard wood</td>
<td>0.004</td>
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<tr>
<td>Logging residues</td>
<td>0.08</td>
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<tr>
<td>Milled peat</td>
<td>0.20</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>0.20</td>
</tr>
<tr>
<td>Olive stones</td>
<td>0.06</td>
</tr>
<tr>
<td>Pine bark</td>
<td>0.15</td>
</tr>
<tr>
<td>Pine chips</td>
<td>0.06</td>
</tr>
<tr>
<td>Pitchy wood</td>
<td>1.74</td>
</tr>
<tr>
<td>Rape cakes</td>
<td>0.04</td>
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<tr>
<td>Salix</td>
<td>0.02</td>
</tr>
<tr>
<td>Sawdust</td>
<td>0.05</td>
</tr>
<tr>
<td>Spruce bark</td>
<td>0.28</td>
</tr>
<tr>
<td>Spruce chips</td>
<td>0.04</td>
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<tr>
<td>Triticale</td>
<td>0.01</td>
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<tr>
<td>Wood pellets</td>
<td>0.09</td>
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<tr>
<td>Wood pellets II</td>
<td>0.10</td>
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</table>
BioNorm II obtained 26 of 30 points in the evaluation and is on a special list with other promising proposals which will be preferred when further resources are available.

- Instrumental methods for rapid tests and On-line measurements
- Developing of methods for Bridging properties, impurities and particle size distribution
- Validation of the classification system of biofuels by handling and combustion tests
- Sampling and sample reduction of biomass from southern Europe

Summary

- BioNorm has developed improved sampling and testing procedures and assessed the limitations of existing procedures in detail.
- The quality assurance system developed in BioNorm allows for biofuel provision of quality according to customer demands.
- The integration of the NMS/NAS into the work of BioNorm ensures that the standardisation requirements of these countries are considered.
- Due to the close link to the work of CEN TC 335 “Solid Biofuels”, an excellent exploitation of the results is guaranteed.
- BioNorm has contributed significantly to the development of highly sophisticated standards.
Thanks for your attention!
Annex 6. Preparation of fuels based on waste material
Sture Mattsson
## SWEDEN´S UNIQUE SITUATION

<table>
<thead>
<tr>
<th>Resource</th>
<th>Status</th>
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<tr>
<td>OIL</td>
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<tr>
<td>GAS</td>
<td>NO</td>
</tr>
<tr>
<td>COAL</td>
<td>NO</td>
</tr>
<tr>
<td>WOOD</td>
<td>YES!</td>
</tr>
<tr>
<td>WASTE</td>
<td>YES!</td>
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</tbody>
</table>
FUEL PREPARATION

TRADITIONAL

FUEL PREPARATION

FlexHammer™

UP TO DATE
Fuel Based on Waste Materials

FACTORS of influence to the incineration control

1. COMPOSITION
   - Type of community
   - Structure of industry
   - Communication community-industry-waste company

2. HOMOGENEITY
   - Collection
   - Feeding
   - Design of storage, in – out order
   - All steps through

3. HUMIDITY
   - Preparation order
   - Storage volume
   - Design of storage, in – out order

4. PARTICLE SIZE
   - Preparation equipment
   - Equipments’ flexibility
High Quality fuel for BFB & CFB boilers

Means Improved incineration
- No organics in ashes
- Simple gas cleaning
- Less NOX
- Less emissions
- Increased temperature
- Increased pressure

Saying 1:
- Grate boilers need no fuel preparation…..but
- Grate boilers have high demand on AVAILABILITY
  Zero acceptance regarding production breakdowns is very demanding
- A breakdown means no energy delivery out and no waste delivery in and millions/day in lost money

Saying 2:
- "Design-fuel" doesn’t exist

Saying 3:
- Guaranteed "clean" material never arrives
FlexHammer™

5 Sizes

<table>
<thead>
<tr>
<th></th>
<th>Rotor diam.</th>
<th>Power Range</th>
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<tr>
<td>FH 1200</td>
<td>1200</td>
<td>130-315 kW</td>
</tr>
<tr>
<td>FH 1500</td>
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<td>130-315 kW</td>
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<tr>
<td>FH 1800</td>
<td>--</td>
<td>160-400 kW</td>
</tr>
<tr>
<td>FH 2000</td>
<td>1600</td>
<td>500-800 kW</td>
</tr>
<tr>
<td>FH 2400</td>
<td>--</td>
<td>615-1000 kW</td>
</tr>
</tbody>
</table>

**FlexHammer™ Flexibility**

Variable speed makes it possible to take full advantage of installed motor power by variations in feed materials’ analysis or supply.
FlexHammer™ Flexibility

Closed Door
- Processing over bottom grate, fine fractions

Open Door
- Precrushing, bypassing the grate, coarse fractions e.g.,
  processing railway sleepers with steel

“Knives” Comb/Anvils
An item, very important, specifically when processing elastic objects such as plastic folios and textiles.
Necessary in the “uncrushable objects” release system, the reject door function.
FlexHammer™ Flexibility

Grate
- Installed / Not installed / Partly installed
- Several opening dimensions
- Several opening combinations
- Steel bars- alt. Steel plate design

FlexHammer™ Flexibility

Hammers
- Several shapes and qualities
- Several numbers and positioning patterns
- Several sizes

Std 11 kg 11 alt. 22 kg
62 kg
Size Distribution Diagram for mixed Swedish household- and industrialk waste, processed over 120mm grate
Annex 7. Deposit formation during combustion of different waste wood qualities and co-combustion of waste wood and sewage sludge
David Eskilsson
Deposit formation during combustion of different waste wood qualities and co-combustion of waste wood and sewage sludge

David Eskilsson
SP Swedish National Testing and Research Institute

Lars-Erik Åmand
Chalmers, Department of Energy technology

Agenda

- Introduction
- Chemical content of different waste wood qualities
- Deposit formation during combustion of waste wood in a grate furnace
- Deposit formation during combustion of different waste wood qualities in a CFB
- Deposit formation during co-combustion of waste wood and sewage sludge in a CFB
- Conclusions
Introduction

Demolition wood = Waste wood

Waste wood: Sorted demolition wood from old buildings and wood packing material. These materials are crushed to a suitable fuel size.

Waste wood can contain different amounts of:
Metals (nails and fittings), creosote, plastic, gypsum, board

In some countries different classes of waste wood exists.

Waste wood often contains higher amounts of Zn, Pb, Cl and S compared to virgin wood. Causes problems with increased deposit formation and corrosion on super heaters.

ZnO and PbO were used as a pigment in old paint

Chemical content of some different waste wood qualities – Na, K, Cl and S

Swed: Swedish waste wood qualities
Imp: Imported waste wood qualities
Chemical content of some different waste wood qualities – Zn, Pb and Cu

Swed: Swedish waste wood qualities
Imp: Imported waste wood qualities

Example of deposit formation during waste wood combustion
Deposit formation during waste wood combustion Händelö P11 – Vibrating grate

Combustion of imported waste wood with high chlorine content (0.14 w%) – Deposit content

Flue gas temperature: 900 °C
Metal temperature: 500 °C
Melting point of deposit: 400 °C

Measured by Vattenfall
Combustion of Swedish waste wood with low chlorine content (0.04 w%) – Deposit content

Flue gas temperature: 900 °C
Metal temperature: 500 °C

Measured by Vattenfall

Combustion of different waste wood qualities and co-combustion of waste wood and sewage sludge in a CFB

Experiments have been performed in Chalmers 12 MW CFB
### Experimental - Fuels

Almost equal amounts of wood pellets and demolition wood were fired. In some cases sewage sludge was added.

Three different demolition wood qualities were simulated in a reproducible way:

1. “Clean” demolition wood
2. Painted demolition wood: Added ZnO (pigment in old paint)
3. Painted demolition wood with high chlorine content: Added ZnO and HCl

### Experimental – Test program

WP: Wood Pellets  
MS: Municipal Sewage sludge  
Number: mass dry fuel / mass total dry fuel

<table>
<thead>
<tr>
<th>Runs</th>
<th>Molar ratio</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cl/Zn</td>
<td>S/Zn</td>
<td>Cl / (K+Na)</td>
<td>2S / (K+Na)</td>
<td>2S/Cl</td>
<td></td>
<td></td>
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<tr>
<td>WP38</td>
<td>4.4</td>
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<td>WP33+MS13</td>
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<tr>
<td>WP56+ZnO</td>
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<td>WP48+ZnO+MS5</td>
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<td>0.16</td>
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<td>7.5</td>
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<td>WP47+ZnO+MS9</td>
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<td>5.9</td>
<td>0.16</td>
<td>1.9</td>
<td>11.9</td>
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<td></td>
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<tr>
<td>WP51+ZnO+HCl</td>
<td>4.0</td>
<td>0.63</td>
<td>1.9</td>
<td>0.6</td>
<td>0.3</td>
<td></td>
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<tr>
<td>WP44+ZnO+HCl+MS6</td>
<td>3.9</td>
<td>3.8</td>
<td>0.80</td>
<td>1.6</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WP43+ZnO+HCl+MS10</td>
<td>3.5</td>
<td>5.9</td>
<td>0.51</td>
<td>1.7</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results – Deposit formation

Added sludge

Results – Chemical analysis of the deposits
Results – Mass size distribution of the fly ash measured by a DLPI

Results - Sum of elements related to fouling in fly ash particles (K, Na, Zn, Cl and S)
Conclusions - waste wood combustion

- Waste wood often has a higher content of chlorine, sulphur, zinc, lead and copper compared to virgin biomass.

- High amount of chlorine in the fuel increases the deposit formation and give a deposit with higher chlorine content.

- Zinc can in some cases evaporate from the combustion chamber and form deposits. In these studied furnaces the zinc evaporation was high during grate fired conditions.

- Zinc can lower the melting point of the deposit and increase the corrosion rate.

The results from the combustion tests at Chalmers CFB have been reported in: Lars-Erik Åmand, Bo Leckner, David Eskilsson, and Claes Tullin, “Ash Deposition on Heat Transfer Tubes during Combustion of Demolition Wood”, Energy & Fuels, 20 (3), Pages 1001 -1007, 2006,
Conclusions - Co-combustion of waste wood and sewage sludge

- The deposit formation decreases radically when sludge is added to the combustion
- The fouling related elements (mainly KCl) in the submicron particles is transported to the bigger particles (Dp>1 µm) during sludge combustion
- During high S/Cl ratios, the potassium is sulphated
- Looking at the results from the elemental concentration of the bigger particles during sludge combustion indicates that a major part of the potassium could have reacted with aluminum-silica compounds
- Sludge contain high amounts (10 % dry basis) of zeolites (aluminum-silica compound) which derive from phosphate free washing detergent.


Acknowledgement

Financial support from the Swedish Energy Agency and from Värmeforsk AB

Thank you for your attention!
Annex 8. Experience from waste co-combustion in Vattenfalls fluidized bed boilers
Matts Almark
Experience from waste co-combustion in Vattenfall fluidized bed boilers

Matts Almark

Co-combustion, waste & biofuels

- Waste fractions containing unwanted elements
  - Chloride, alkali, heavy metals
- Increased fouling & corrosion compared to “clean” biofuels
- Some experiences and observations with different amounts of waste derived fuels in fuel mix
- Measurement of alkali chlorides in flue gas - monitoring fuel quality
- Additives and other solutions
- Myllykoski, Idbäcken, Munksund
Munksund

- CFB
- 96 MWth
- Bark (> 80%)
- Sawdust, woodchips
- Cardboard reject (< 6%)

Myllykoski

- BFB
- 88 MWth
- Bark, peat, forest residues, sludge, recycled wood
- (Recycled Energy Fuels)
Idbäcken

- BFB
- 105 MWth
- Biomix + Recycled wood (50%)

Fuel chemistry derived problems - characterization

- Measurement of gaseous alkali chlorides – IACM
- Deposit probes
  - Fouling rates
  - Deposit chemistry – corrosion rates
IACM – In situ Alkali Chloride Monitor

- UV lamp and detector

IACM as fuel quality monitor

(Biofuel boiler)
Reduction of alkali chlorides - ChlorOut

- \((\text{NH}_4)_2\text{SO}_4 \rightarrow 2\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O}\)
- \(\text{SO}_3 + \text{H}_2\text{O} + 2\text{KCl} \rightarrow 2\text{HCl} + \text{K}_2\text{SO}_4\)
- Also reduction of \(\text{NO}_x\) and CO emissions

Munsund

- No waste; waste addition; waste + ChlorOut
- Measured levels of KCl and deposit chlorine content
Normal & with ChlorOut addition

Without ChlorOut
Chloride conc. 12%
deposits 6 g/m²/h

With ChlorOut
Chloride conc. <0.2%
deposits 2 g/m²/h

Bio/recycled wood 50/50

Without ChlorOut
Chloride 25%
Fouling rate 21 g/m²/h

With ChlorOut;
Chloride <0.2%
Fouling rate 6 g/m²/h
Myllykoski K7

- Operating on a wide mix of fuels
- Peat, bark, forest residues, sludge
- Recycled wood, recycled energy fuels
- REF (~5%)

- High levels of S from peat and sludge
- S/Cl or S/alkali above what usually considered critical limits

Myllykoski K7, IACM

- Removal of REF from fuel mix; week 50/2005 & 2006
Idbäcken

- Removal of coal from fuel mix
- Increasing fouling and corrosion
- ChlorOut as S-additive
- SH replaced to E1250

Idbäcken, fuel distribution over bed

- With increasing share of recycled wood problems with deposit formation over fuel feed points
- Uneven temperature in bed – problems reaching high loads
- Mixing in freeboard

- Improved fuel feeding system - reduced deposit formation
  - Reduced amounts of fines and rapidly volatilized burning immediately above fuel feed points
  - More even heat release in bed
Idbäcken, fuel distribution table

CO concentrations (Johannes BFB)

- CO concentrations from the right side wall (m)
- Approx. position for fuel injection
Idbäcken, remaining issues

- Deposit formation in furnace wall
- Furnace wall corrosion

Bed fluidization issues – metal waste

- With recycled fuels in certain cases high amounts of incombustible matter, metal waste
- Nails in recycled wood
- Will not fluidize in the bed, decreased mixing
- Forming defluidized zones
- Difficulties removing metal waste with bed bottoms not designed for the task
Removal of metal waste (Myllykoski)

- Nails forming tangled lumps
- Manually removed

“Rassausaukko”

- Bed bottom manually cleaned without need for shut-down
- Reduced load on natural gas
Conclusions

- Waste fractions can be co-combusted with biofuels
- Feed arrangement must be looked over
- Spreading of fuel – especially in BFB:s
- Increased fouling & corrosion risk compared to “clean” fuels
- Increased amounts of chlorine, alkali, heavy metals
- Bed bottom capacity to deal with (metal) waste

Conclusions (2)

- Fuel quality can be monitored with IACM
- SH fouling rates correlating with measured alkali chloride levels
- Additives (ChlorOut) – reduction of alkali chlorides, fouling rate and corrosion risk
Annex 9. Fuel flexibility through (co-)firing biomass in Belgian pulverised coal power plants
Yves Ryckmans
BELGIUM HAS GREEN CERTIFICATE SYSTEMS

- 3 systems (one per region)
- Compatibility is technically feasible but excluded by law except OK between Brussels and Wallonia
- Growing target calculated on the base of yearly electricity sales for each supplier
- Penalty between 75 and 125 €/certificate or 7.5 to 12.5 €c/kWh
  - but only a part of the benefit according to energy balance
- Regulatory body in each region
- Market of green certificates: market value < penalty
- Today: stable market value
BIOMASS TECHNOLOGIES

- Modern coal power plants can accommodate biomass, e.g., Avedore PF (Dk), Buggenum ICCG (NL).
- Firing biomass in dedicated plants equipped with grate boilers or Fluidised Beds, depending upon capacity (20-35 MW).
- Feedstock: cheap local biomass.
- Investment at least 3 times more expensive.
- Co-gasification of biomass (like Ruien), capacity depending upon dryness of feedstock.
- Feedstock: cheap local biomass or waste.
- Retrofit of existing coal power plants, like Awirs 4).
- Feedstock: expensive imported biomass.
- Mixing bio-fuels with coal (with co-milling or separate injection).
- Nearly no investment, (cheap) waste or more expensive biomass.

**CFB PP**

- Indirect co-firing with partial gasification.
  - Hot syngas at 850°C.
  - Biomass gasifier.

- Direct co-firing with common injection.
  - Biomass dust from coal mill.

- Direct co-firing with separate injection.
  - Grate combustion.

- Biomass dust from coal mill.
- Boiler.
Which kind of biomass? How is it used?

Reference:
With an electrical efficiency of 36 %, 1 ton hardcoal generates approx. 2,5 MWh

( Co-)firing bio-fuels today:

- sewage sludge: mixed with coal 1 kg ⇒ ~ 1,0 kWh
- olive cake: mixed with coal 1 kg ⇒ ~ 1,3 kWh
- coffee ground: mixed with coal 1 kg ⇒ ~ 1,6 kWh
- wood dust: injected after mills 1 kg ⇒ ~ 1,8 kWh
- wood chips: syngas injected 1 kg ⇒ ~ 0,8…1,5 kWh
- wood “pellets”: hammer mills 1 kg ⇒ ~ 1,8 kWh
CRITICAL POINTS
Thermal plant

Critical points of co-firing biomass with coal

1. Storage
   Health, fire, ...
2. Milling
   Mechanical problems, fire, explosions (volatiles)
3. Furnace
   Slagging, corrosion (reducing atmosphere !)
4. Super-heater
   Fouling, HT-corrosion (Cl, K)
5. Economizer
   CaSO₄ deposits
6. High-dust DeNOₓ
   Catalyst deactivation (K, P, As, Ca)
7. Air heater
   Blockage, LT-corrosion, ...
8. ESP
   Efficiency (S)
9. By-products
   Valorization ash in cement & concrete (Ca, P)
10. DeSOx
    Waste water, gypsum quality
11. Stack: emissions
    Legal aspect: permits
Use of coal roller mills for biomass

- Wear is caused by minerals which are both coarse and hard
- Power consumption is influenced by:
  - Particle size before grinding
  - Particle size needed after grinding
  - Type of coal or value of HGI
  - Moisture content
- With fibrous biomass risk of
  - agglomeration
  - vibrations and mechanical trouble
  - fires

RECENT DEVELOPMENTS

- 2005:
  - Wood dust: Langerlo: + ~ 20 MW O.K.
  - Firing « wood pellets »:
    - Rodenhuize: co-combustion: ~ 65 MW test run
    - Awirs (Liège): 100% pellets: ~ 70 MW ~O.K.
  - Olive cake:
    - + Mill efficiency enhancements: total + ~ 5 MW
  - Coffee Grounds: Mol
- 2007:
  - Wood chips milling: Ruien: ~15 MW
Ruien Power Station

WOOD DUST IN RUIEN

- Weighing balance
- Trucks with container
- Raw coal
- Air
- Power

Ruien3
Ruien4
Ruien5
WOOD CHIPS CFB GASIFIER RUIEN

Biomass : 100 000 ton/a ~9%

Processing

Coal 500 000 ton/year ~91%

Gas flame

Coal Ramas

540 °C

180 bar

540 MW

CO₂ Reduction ~ 120 000 ton

fly ash

✓ 120.000 mt/year wood chips
✓ 17 – 28 MWe
✓ 30-50% d.m. moisture

Concept of biomass co-firing in Ruien PP

✓ 40.000 mt/year olive cake
✓ 8 MWe

✓ 40.000 mt/year wood dust
✓ 10 MWe

✓ 120.000 mt/year wood chips
✓ 30% moisture
✓ 22 MWe

✓ coal
✓ 130 MWe
Ruien bio-power plant today

- Ruien 1 & 2 shutdown
- Ruien 3, 130 MW coal, 130 MW oil
- Ruien 4, 200 MW coal, 300 MW oil, 20 MW Gasifier
- Ruien 5, 200 MW coal, 300 MW oil, 20 MW Gasifier
- Ruien 6, 300 MW Gas/oil
- Ruien 3, 130 MW coal, 130 MW oil
- Ruien 4, 130 MW coal, 130 MW oil

Ruien 3, 4, 5 Wood dust 10-12 MW

WOOD DUST IN LANGERLO

- 100,000 mt/year wood dust, 90% dm
- 28 MWe
WOOD PELLETS

WOOD PELLETS TRANSPORT

SILO'S

4 hammer mills

milling

boiler unit 4

burners

4 primary air lines

350,000 mt/year wood pellets

80 MWe

STORAGE:
Self-heating prevention

DESIGN
RODENHUIZE 4

Foucault non-ferro separation

Dust containment conveyor belts
WOOD PELLETS IN AWIRS-4

- 350.000 mt/year wood pellets
- 80 MWe

AWIRS4-DESIGN

- all conveyors fully covered
- Magnetic detection

HOPPER
Wood dust

CENTREX 2
CENTREX 1

TDB0
FILTER 1
FILTER 2
FILTER 3

R2 selection
TR5
TDB3
old coal conveyor (350 m)
Line-up of the belt

TDB2
TDB1
wood dust
Magnetic detection

all conveyors fully covered
TECHNICAL ISSUES
HAMMER MILLS
- Plugging of the sieves (holes of 2.5 mm)
- Wood dust bridging
- Hammer wearing
- Capacity linked to pellet quality
- Abrasion steel elements

Awirs 4
- 2 BVO mills
- 25 ton/h each
- 90% part. < 1.0 mm
- 1 mill ➔ 8 burners
- feed all burners

Rodenhuize 4
- 4 Sprout - Matador mills
- 10 ton/h each
- 99% part. < 1.5 mm
- 1 mill ➔ 2 burners
- feed middle burner row

Liquid bio-oils
Additional alternative liquid biofuels available:
- Palm oil
  ➢ greatest potential available (Malaysia = 25 mil. ton/a)
  ➢ not always produced on a sustainable base
  ➢ cost 300 – 600 €/t
- Oils of coco, rapeseed, soya, sunflower
  ➢ more expensive
- Recycled fry oil
  ➢ cost 300 €/ton
  ➢ potential limited
  ➢ waste stream
INSTALLED CAPACITY WITH BIOMASS

2004 : 60 MW
- Ruien : wood dust ~ 8 MW
- Ruien : gasification of clean wood chips ~ 17 MW
- Langerlo, Rodenhuize, Ruien : olive cake ~ 31 MW
- Langerlo : sewage sludge ~ 4 MW

2005 : 246 MW
- Ruien wood dust ~ 10 MW
- Ruien : gasification of clean wood chips ~ 20 MW
- Langerlo : wood dust ~ 28 MW
- Langerlo, Rodenhuize, Ruien : olive cake ~ 34 MW
- Langerlo : sewage sludge ~ 4 MW
- Mol : coffee ground ~ 2 MW
- Awirs wood pellets ~ 80 MW
- Rodenhuize wood pellets ~ 66 MW

2007 : 261 MW
- Ruien wood pulverisation (Biostof) ~ 15 MW

EVOLUTION GREEN POWER ELECTRABEL

<table>
<thead>
<tr>
<th>Biomass source</th>
<th>ton/a</th>
<th>Power plant</th>
<th>Capacity MW</th>
<th>GREEN Certificates</th>
<th>Avoided ton/y CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>402 000</td>
<td>biomass</td>
<td>246</td>
<td>610 000</td>
<td>611 000</td>
</tr>
<tr>
<td>2006</td>
<td>782 200</td>
<td>biomass</td>
<td>246</td>
<td>1 007 300</td>
<td>1 258 700</td>
</tr>
</tbody>
</table>
MAIN DIFFICULTIES

- **L**: Logistics and organization (volume !)
- **A**: Administrative: stability of regulations?
  - Operation license
  - Emissions regulations
  - Green Certification
- **S**: Supply: market growing, prices rise
- **T**: Technical: specific technical adaptations

→ *Long delays = loss of opportunities*...

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Five reasons for you to choose Laborelec:

- You have one-stop shopping for your energy needs
- You get access to more than 40 years of experience
- You get rapid service with reliable solutions
- You increase the profitability of your installations
- You benefit from independent and confidential advice

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The technical Competence Center in energy processes and energy use. From R&D to operational assistance.
Annex 10. Wet bio-fuels - Aspects on furnace design and boiler operation
Niklas Berge
Wet biofuels –
aspects on furnace design and boiler operation

Niklas Berge, Henrik Brodén
TPS Termiska Processer AB
www.tps.se

Fuel properties
- Moisture content 30 – 60 %
- Ash content (dry base) 0.3 – 6
- Lower calorific value (a.r.) 6 – 14 MJ/kg
- Adiabatic temperature 1050 – 1450°C
- Volatile content (dry base) 70 – 85 %

National and EU emissions restrictions
The topics has been under continues research and methods development in the “TPS Multi Client Research Programme for District Heating Utilities”
Research program organisation

- Steering comity
- Gratefiring
- FB-combustors
- Burners
- Complementary R&D

Bad penetration of secondary air
Uncontrolled recirculation zones
Freeboard of furnace

Mixing gases from grate
Even air supply
Maintain temperature
Control of emissions
Fuel flexibility
Low O₂

Contract the flow and use recycled flue gas for mixing
"Gas throat"

Staggered nozzles for secondary air and flue gas recirculation
Staggered nozzles

Simple retrofit in existing boilers

Improved control of CO and NOx

Reducing heat transfer to improve fuel flexibility
Control off the primary combustion on the grate

- Optimise the drying of the biofuel
- Fast and stable ignition control of the fuel bed
- Controlled burn out of the bottom ash

Control of burn-out with IR-detection
Control of burn-out with IR-detection

Content of unburnt in bottom ash vs. surface temperature

Burn-out controlled by primary air flow in late grate zone

Two front combustion

Torkning
Avgasning
Koksförbränning
Measuring the grate rod temperature

Temperature measured with thermocouples close to the surface of the grate rod.

High temperatures already in the “drying zone”
TPS dynamic grate model

- The model predicts grate and bed temperature, height and oxygen concentration
- Heat transfer in the grate rods
- Dynamic of the bed at changes in the input conditions
- Simulates both top, bottom and mixed ignition of the bed

Conclusions bed model

- Combustion near the grate often starts already within 1 m from the fuel inlet
- Temperature indication and control can be used to control the distribution of primary air and early indication of changes in moisture content
- Grate rod temperature is affected by a complex relation of several parameters
- Model can be used to compute temperature variations
Conclusions

To achieve good fuel flexibility in a boiler it is necessary to have:

- Good measurements of temperature in both primary and secondary combustion zones
- Control of the aerodynamics of the freeboard combustion
- Good control of input parameters such as air and recycled flue gas distribution
- Heat transfer properties of boiler for worst possible case with recycled flue gas for controlling temperature
- Control of air supply to grate and temperature distribution
- Individual control of ash burn out
- Good understanding of effect of and interaction between control parameters
Discussion & Conclusions

- Market issues
- Fuel characterisation and standardisation
- Fuel preparation
- Fuel quality and deposit formation/emissions
- Boiler design

"Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?"

In summary ....

Yes!
- Increased fuel flexibility gives advantages on the market

But...
- Higher costs for operation and maintenance

Requirements:
- Technology
- Competence (knowledge and/or experience)
## Market Issues

"Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?"

<table>
<thead>
<tr>
<th>Yes!</th>
<th>But….</th>
</tr>
</thead>
</table>
| • Bioenergy market increases!!  
• Competition for fuels increase  
• “Conventional” fuels limited  
• Closed loops: Waste => Fuel (legislation important)  
• Energy crops/fast growing tree plantations  
• Many fuels attractive in co-firing | • Competence to use “difficult to burn”/new fuels limited”  
• Technical development necessary (small and large scale; dedicated combustion or co-firing)  
• Fuel quality very varying  
• Minor fractions  
• Unsecure availability  
• ”Disturbances” (taxes, directives, …) |

## Fuel characterisation and standardisation

"Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?"

<table>
<thead>
<tr>
<th>Yes!</th>
<th>But….</th>
</tr>
</thead>
</table>
| • Extensive on-going efforts in developing relevant biomass fuel characterisation methods for sampling and analysis | • Methods not yet available  
• Some fuel fractions very hard to characterise  
• Fuel fractions can be very heterogeneous |
## Fuel Preparation

"Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?"

<table>
<thead>
<tr>
<th>Yes!</th>
<th>But….</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Market driven fuel development of the fuel preparation process&lt;br&gt;• Good fuel preparation =&gt; better combustion performance&lt;br&gt;• Increased sorting of waste =&gt; improved possibilities</td>
<td>• Some fuel fractions very difficult to handle&lt;br&gt;• Costs can be high&lt;br&gt;• Technical development required (on-line analysis, ..)</td>
</tr>
</tbody>
</table>

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## Fuel Quality and Deposit Formation/ emissions

"Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?"

<table>
<thead>
<tr>
<th>Yes!</th>
<th>But….</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Increasing competence on mechanisms, new materials etc&lt;br&gt;• Technical solutions to reduce problems available&lt;br&gt;• Significant experience available from &quot;learn by doing&quot;</td>
<td>• Higher steam data =&gt; more problems!&lt;br&gt;• Improved scientific knowledge on ash chemistry required</td>
</tr>
</tbody>
</table>
### Boiler Design

"*Fuel Flexibility in Biomass Combustion - The Key to Low Bioenergy Costs?*

<table>
<thead>
<tr>
<th>Yes!</th>
<th>But….</th>
</tr>
</thead>
</table>
| • Extensive experience gathered from commercial scale operation  
  – Dedicated biomass  
  – Co-firing | • Design criteria has to be considered |