Recent Developments and Future Prospects for Biomass Combustion from Small to Large Scale

Prof. Dr. Ingwald Obernberger

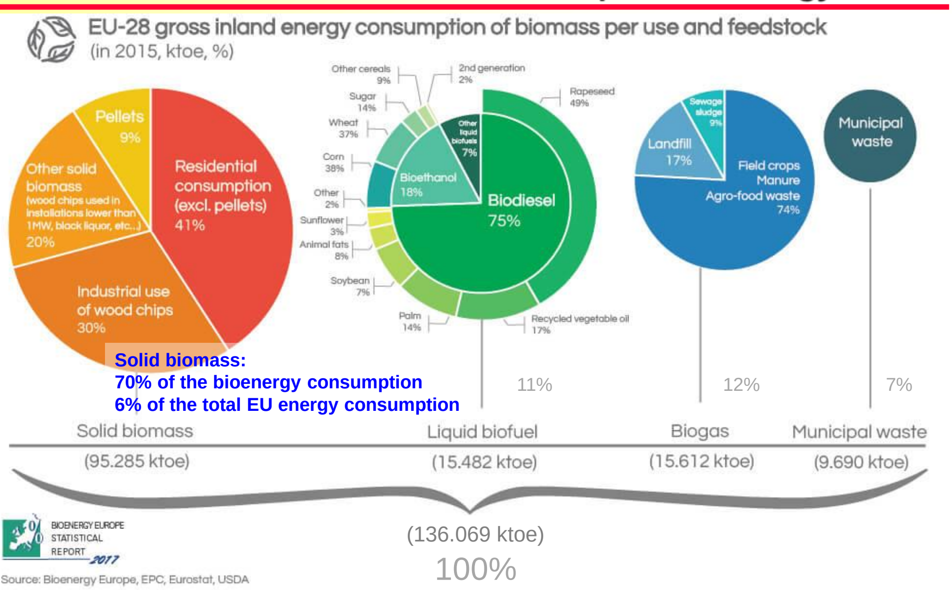
BIOS BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz, Austria
TEL.: +43 (316) 481300; FAX: +43 (316) 4813004
E-MAIL: office@bios-bioenergy.at
HOMEPAGE: http://www.bios-bioenergy.at

Contents

Introduction

- Biomass combustion is the oldest and most mature technology for thermal biomass conversion
- Driven by steadily increasing demands regarding thermal efficiencies and emission reduction a strong technological development has been recognised during recent decades
- Nowadays a broad range of technologies for different solid biomass fuels in all capacity ranges exists
- Consequently, biomass combustion plays a major role in achieving the renewable energy targets of the EC
- However, increasing the share of heat and power production from biomass must be accompanied by sustainable fuel utilisation as well as minimum emissions and maximum efficiency

The role of biomass combustion in the European bioenergy sector

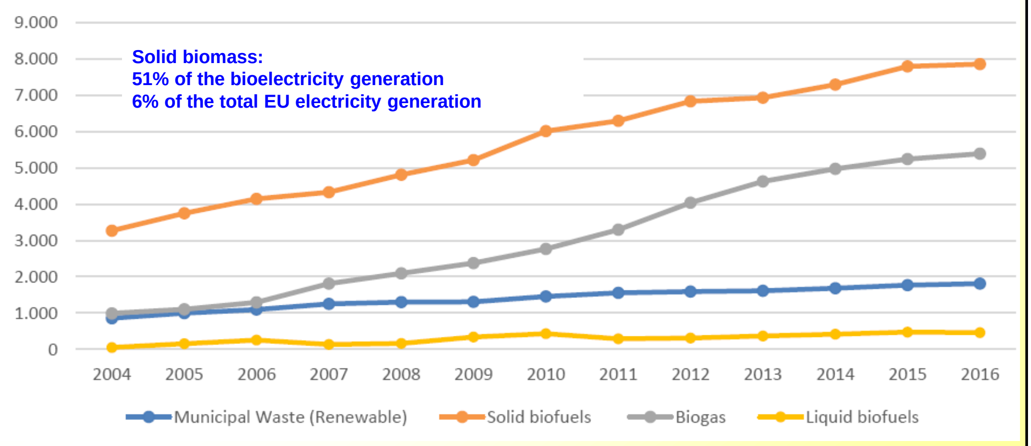


Source: Bioenergy Europe, EPC, Eurostat, USDA

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

The role of solid biomass fuels in the European bio-electricity sector

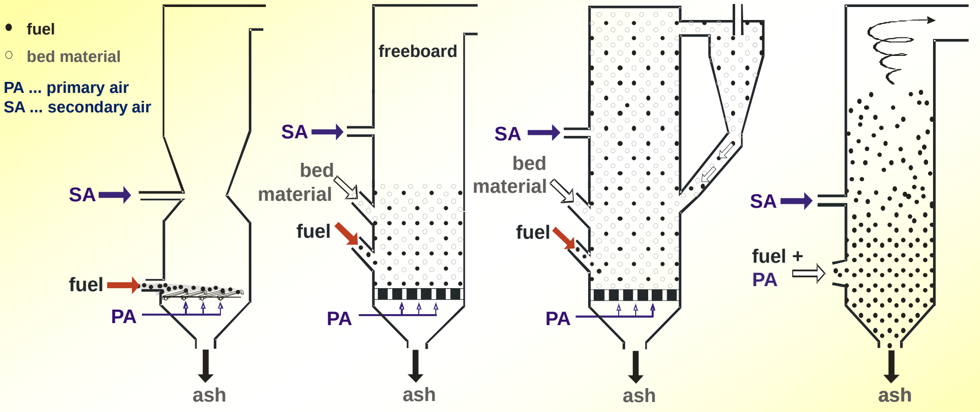
Evolution of the gross electricity generation from biomass by type in EU28 (ktoe)



Source: Bioenergy Europe Statistical Report 2018

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Solid biomass combustion technologies – overview



Fixed-bed	Bubbling fluidised bed	Circulating fluidised bed	Pulverised fuel
0.005 – 50 MW Residential heating District heating CHP	> 20 MW District heating Industrial heating CHP	> 50 MW Industrial heating District heating Co-firing, CHP	1 – 100 MW Wood industry Co-firing

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Ongoing developments and future targets

	Current status	Future development target
Fuel		
Small scale	High quality fuels • **Wood pellets** (EN ISO 17225-2-A1) • **High-quality wood chips**	• **Towards increased fuel flexibility** (e.g. agricultural residues, biogenic waste materials, non-wood fuels)
Medium and large scale	• Plants tailored to the demands of specific biomass fuels • Only restricted fuel flexibility within one plant	• **Strategic approaches** • fuel design • combustion technology design
Emissions		
	Emissions according to present and upcoming emission limit (e.g. Ecodesign, MCP directive)	• Towards almost zero emissions for CO, OGC and PM • Towards almost zero emissions for NOx
Efficiencies		
All scales	85- 95% without and ~100% with flue gas condensation	• More than 100% (rel. to NCV) for dry fuel • More than 110% (rel. to NCV) for wet fuel

➔ targets should preferably be reached by primary measures

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Towards enhanced fuel flexibility – fuel design (I)

- **Fuel design is a general approach of using primary fuel based measures to increase the fuel quality and combustion performance**
  - Fuel blending
  - Additivation
  - Fuel pre-treatment by torrefaction or steam explosion

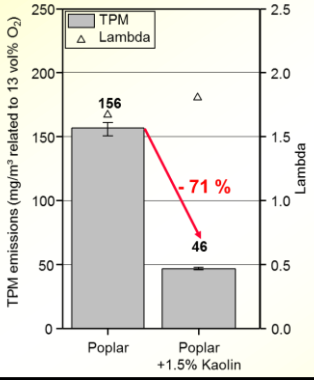
- **Fuel blending**
  - Usually applied to improve the combustion behaviour of in terms of ash formation characteristics problematic biomass fuels
  - Example: blending of biomass fuels with peat can significantly reduce problems with ash melting and fine particulate emissions.

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Towards enhanced fuel flexibility – fuel design (II)

➢ Additivation with inorganic additives

- Kaolin has proven very good performance in improving the combustion properties of in terms of ash related issues problematic biomass fuels
- Kaolin additivation typically decreases particulate matter emissions as well as slagging problems



Results of test runs with pure and additivated poplar in a 30 kW grate-fired boiler

TPM ... total particulate matter emissions downstream boiler

Source: Technology and Support Centre in the Centre of Excellence for Renewable Resources (TFZ)

Guidelines regarding additivation with kaolin are already available from the ERA-NET Bioenergy project BIOFLEX! (https://bioflex-eranet.eu)

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Towards enhanced fuel flexibility – fuel design (III)

➢ Fuel pre-treatment by torrefaction or steam explosion

- **Torrefaction: mild form of pyrolysis at temperatures typically between 200-320 °C**
- **Steam explosion:**
  - biomass is treated with hot steam (180 to 240°C) under pressure (1 to 3.5 MPa)
  - followed by an explosive decompression of the biomass to atmospheric pressure
  - ➔ rupture of the biomass fibres rigid structure

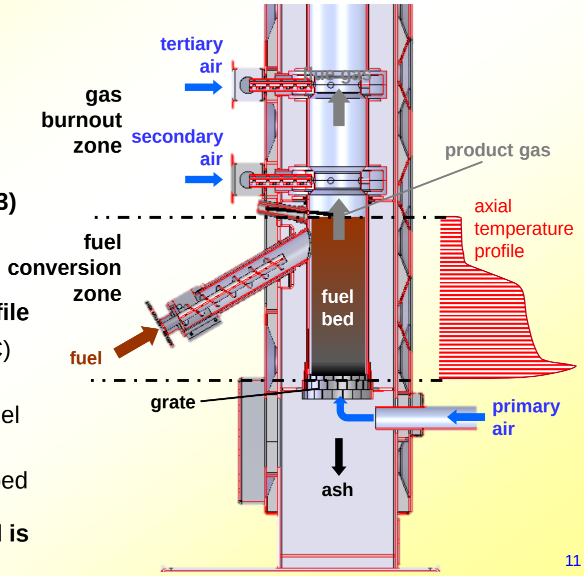
- **Both technologies**
  - make hydrophilic biomass hydrophobic
  - inhibit (torrefaction) or significantly reduce (steam explosion) biological degradation
  - improve milling properties
  - increase energy density
    for pelletised wood: from 7.5 – 10.4 GJ/m³ to 15.0 – 18.7 GJ/m³ (for torrefication)
    to 11.0 – 15.0 GJ/m³ (for steam explosion)
  - reduce costs for transport and storage

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Towards enhanced fuel flexibility and zero emissions – extreme air staging technology

➢ Extreme air staging

- **Fuel is fed from above to a comparably high fuel bed**
- **Primary air passes upwards through the fuel bed (λ ~ 0.2 - 0.3)**
- **Zones with different conversion processes → pronounced temperature profile**
  - Charcoal combustion (~1,000°C)
  - Pyrolysis and gasification at gradually decreasing gas and fuel bed temperatures
  - Drying zone: on top of the fuel bed
- **Product gas leaving the fuel bed is combusted in a gas burner**

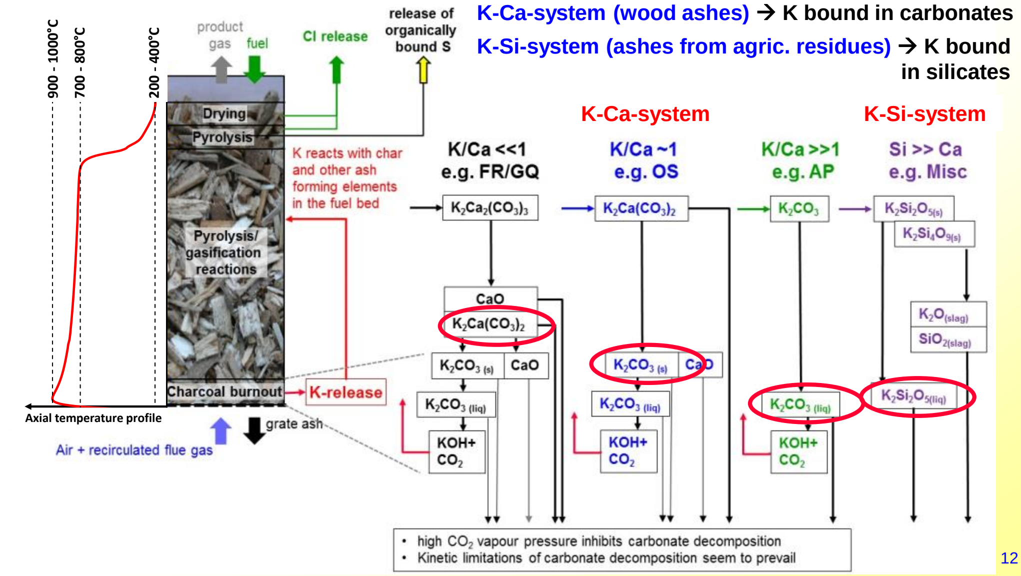


BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Extreme air staging technology – embedding of K in the fuel bed

K-Ca-system (wood ashes) → K bound in carbonates

K-Si-system (ashes from agric. residues) → K bound in silicates



BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

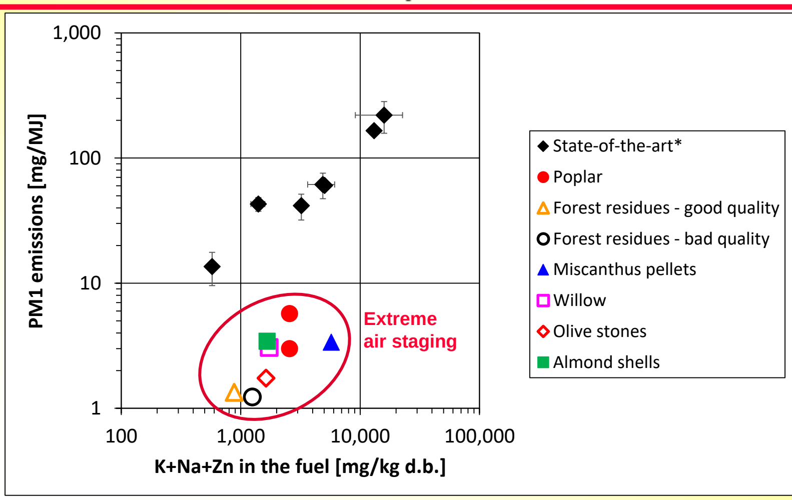
Extreme air staging technology – advantages compared with state-of-the-art fixed-bed combustion systems

	State-of-the-art fixed-bed combustion	Extreme air staging	Advantage
Excess air ratio	**λ = 1.5 – 1.6**	**λ = 1.2 – 1.3**	• **Increased thermal efficiency (about + 2% absolute)** • **Higher dew point of the flue gas (2 - 4°C) enables more efficient implementation of flue gas condensation**
Gaseous emissions	**CO < 50 mg/MJ**	**Practically zero**	• **Very low emissions can be achieved during full and partial load**
TSP emissions	**Increase with plant size and load from some 10 to some 100 mg/MJ**	**< 10 mg/MJ** also for ash rich fuels	• **No dust precipitation devices needed** • **Significantly reduced boiler fouling**
Fine PM emission	**Increase with the K-content of the fuel from ~10 to more than 100 mg/MJ**	**< 10 mg/MJ** also for K-rich fuels	• **No dust precipitation devices (ESP, baghouse filters) needed** • **Significantly reduced boiler fouling**

MJ related to the NCV of the fuel

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

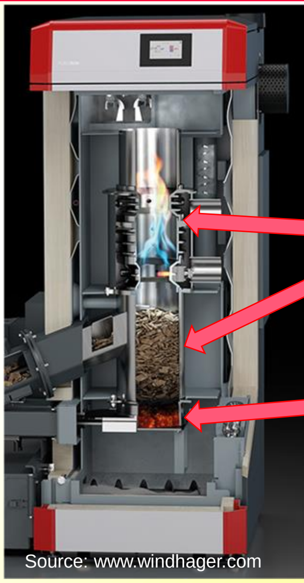
Extreme air staging technology – fine particulate matter emissions



Explanations: Results from test runs with a 50 kW boiler based on an extreme air staging concept;
mg/MJ related to fuel power input (NCV);
* conventionally staged combustion systems; source: OBERNBERGER I., 2014: Strategy for the Application of Novel Characterization Methods for Biomass Fuels: Case Study of Straw. In: Energy Fuels 2014, 28

Extreme air staging technology – applications – small-scale boilers

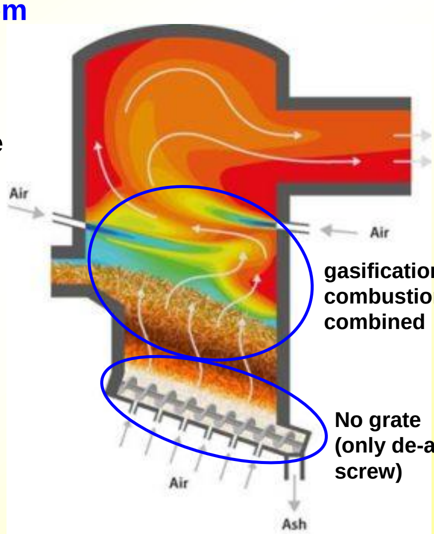
- **PuroWIN technology from Windhager (AT)**
  - **Low-emission combustion** at O_2-contents in the flue gas between 3 and 5 vol%
  - **Flexible load variation** between 25 – 100% is possible
  - **Almost zero** emissions regarding **CO and OGC** at nominal and partial load as well as during load changes
  - **TSP** emissions **below 2 mg/MJ$_{NCV}$** without application of any filter
  - **High efficiencies** of 93 - 94%



Source: www.windhager.com

Extreme air staging technology – applications – medium-scale systems

- **Biomass Gasification Furnace from Dall Energy (DK)**
  - **No grate**
  - **Gas combustion directly above the fuel bed**
  - **High fuel flexibility**
    - moisture content (20 – 60 wt.% w.b.)
    - particle size up to 40 cm
    - ash content up to 30 wt% (d.b.)
  - **TSP emissions below 20 mg / MJ without filter**
  - **4 plants (2 to 9 MW) in operation, 20 MW plant in construction**

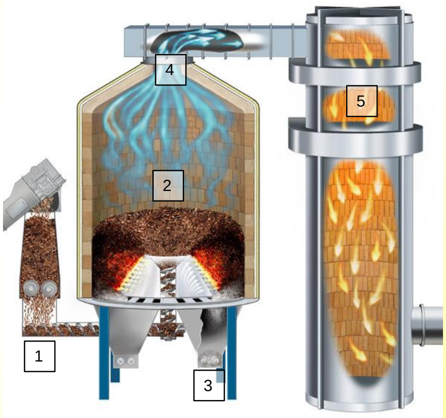


Source: https://dallenergy.com

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Extreme air staging technology – applications – large-scale systems

- **Nexterra's Gasification / Combustion Technology (CAN)**
  - **Product gas combustion in a separated burner connected via a gas duct**
  - **Utilisation of wood, wood residues, bark, non-contaminated waste wood**
  - **Low excess oxygen content (λ = 1.2 - 1.3) and thus high efficiency**
  - **Capacity range: 2 - 40 $MW_{(th)}$**

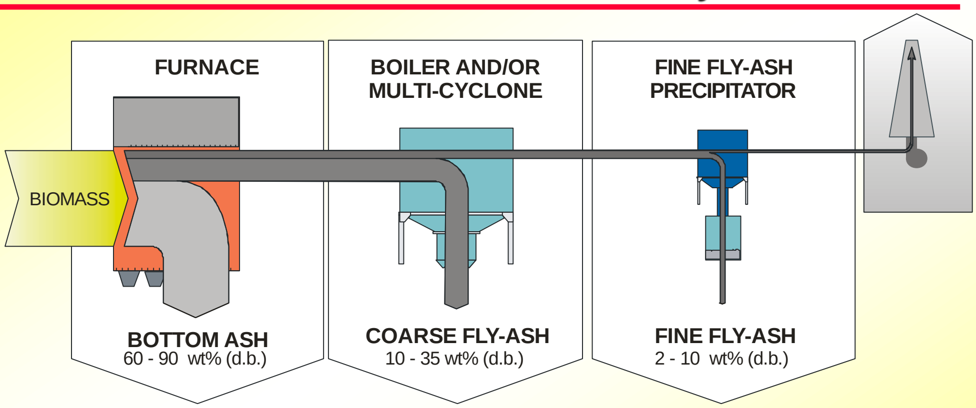


Source: http://www.nexterra.ca

1) Fuel feeding system
2) Gasifier
3) Ash removal system
4) Product gas outlet to oxidiser
5) Oxidser (combustion zone)

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

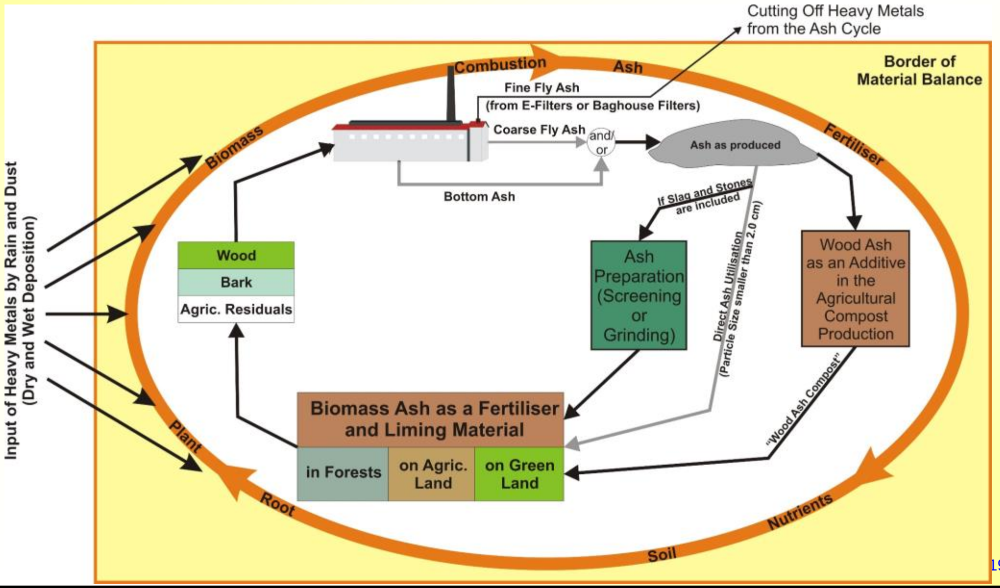
Ash utilisation – ash fractions and heavy metal contents



- **Fertilizing and liming properties of the ash due to Ca, K, P and Mg**
- **Critical heavy metals like Cd and Zn get enriched in the filter fly ash due to their volatility**

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Sustainable ash utilisation – approach



BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Options for sustainable ash utilisation

- **For chemically untreated biomass fuels:**
  - **Ash utilization on agricultural fields**
  - **Ash utilization on forest soils**
  - **Ash utilization as an additive in compost production**
  - **Production of an ash-based fertiliser**
- **Relevant for all options:**
  - **Quality control**
  - **Application control**
- **A common European approach regarding legislation is urgently needed**

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Conclusions

- **Fuel design as an option to increase fuel flexibility and reduce emissions/boiler deposits in existing plants resp. when using conventional biomass combustion technologies**
- **Extreme air staging as an interesting new upcoming technology**
  - **applicable in all capacity ranges**
  - **complete burnout and zero dust based on extreme air staging technology are almost achievable**
  - **further development towards zero NO_x as a future target** (approaches already available)
- **Improve the utilization of residues (ashes):**
  ➔ towards a closure of the mineral cycle
- **Overall future goal:**
  Almost zero emission biomass combustion at highest efficiencies

BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz

Thank you for your attention

Contact:
Prof. Dipl.-Ing. Dr. Ingwald Obernberger
Hedwig-Katschinka-Straße 4
A-8020 Graz, Austria
phone: +43 (316) 481300; FAX: +43 (316) 4813004
Email: obernberger@bios-bioenergy.at
HOMEPAGE: http://www.bios-bioenergy.at