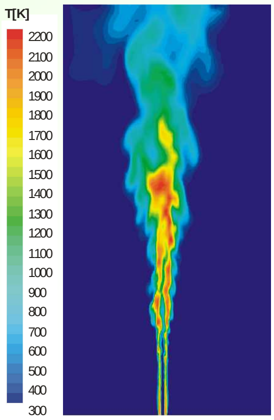
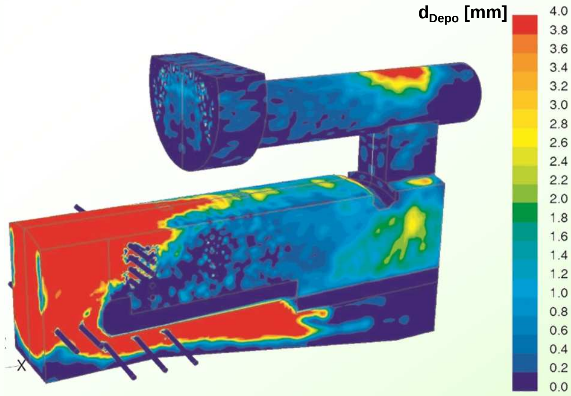
CFD simulations

in the field of thermal biomass conversion

Advantages – Fields of application – Innovations

Overview





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SUSTAINABLE ENERGY BIOMASS ASH ECONOMY

Contribute to an efficient energy system of the future by our research, development and engineering activities

Be the competitors always at least a step ahead regarding Know How, new developments and new applications

What is CFD?

- CFD (Computational Fluid Dynamics) is the spatially (and temporally) resolved simulation of flow and heat transfer processes.
- Flow processes may be laminar or turbulent, they may be reactive or occur in a multi-phase system.
- CFD enables the 3D visualisation of turbulent reactive flows in furnaces and boilers.
- CFD simulations thus constitute an excellent tool for process analysis as well for the design and optimisation of plants.

Advantages of CFD-based plant design

- Improved basic understanding of the processes taking place in combustion, gasification or pyrolysis reactors
- Increased reliability in plant development
- Reduction of development times and costs for test runs
- Increased plant availabilities and operating hours
- Increased fuel flexibility
- Reduced material wear
- Increased plant efficiency
- Reduced emissions
- Smaller plant design

Basic principles and general conditions

- The CFD models consists of an in-house developed empirical grate combustion, fixed bed and entrained flow conversion models complemented with modified and lab-scale tested CFD sub-models (ANSYS Fluent) for the turbulent reactive flue gas flow in the combustion, gasification and pyrolysis reactor.
- In addition numerous other CFD models for different application purposes (e.g. modified combustion model for wood logs, NO_x formation model, aerosol formation model, ash deposition model, tar conversion model, pyrolysis model etc.) have been developed and shall be described in the following chapters.
- The verification of the CFD model was successfully done at lab-scale, pilot-scale and industrial-scale furnaces.
- In the CFD department the following software is applied: ANSYS Fluent, OpenFOAM, FactSage, Chemkin and SolidWorks.

Goals of CFD simulations (1)

- Efficient mixing of gas and oxidising agent
- Improved utilisation of reactor geometries (compact plant design)
- Reduction of local velocity and temperature peaks in order to reduce material erosion and ash deposit formation
- Optimisation of air staging to reduce emissions
- Efficiency optimisation
- Sensitivity analyses (e.g. influence of geometrical changes, load, water content and air staging)
- Efficient temperature control to gain a high fuel flexibility
- Development of combustion systems with minimised emissions and high fuel flexibility

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Goals of CFD simulations (2)

- **Optimisation of the gasification agent and the reactor geometry in order to achieve an as complete as possible gasification as well as a high fuel flexibility and producer gas quality**
- **Optimisation of biomass pyrolysis reactors to reach high charcoal qualities and overall efficiencies**
- **Optimisation of flow, residence time and temperature distribution in gas cleaning units**
- **Development of burners for producer gas, pyrolysis gas and pyrolysis oil**

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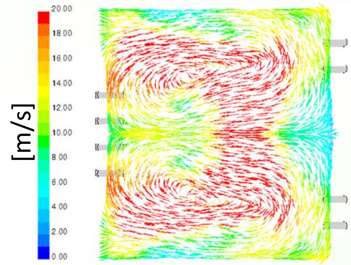
Working fields: CFD-based development and optimisation of biomass combustion plants and boilers (1)

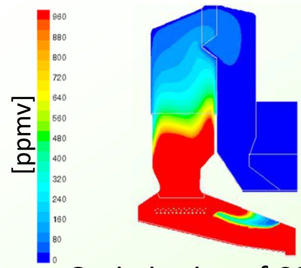
- **Fixed bed and grate furnaces**
- **Pulverised fuel furnaces**

Special aspects:

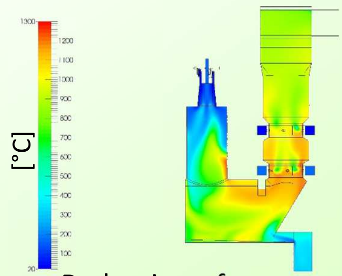
- Optimization of nozzles and air staging
- Reduction of local temperature and velocity peaks
- Reduction of emissions
- Optimization of efficiency
- Increase of fuel flexibility
- Avoidance of dead zones
- Avoidance of erosion by coarse fly ash particles



Optimization of secondary air nozzles



Optimization of CO burnout



Reduction of temperature peaks

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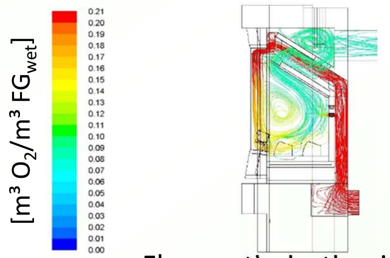
Working fields: CFD-based development and optimisation of biomass combustion plants and boilers (2)

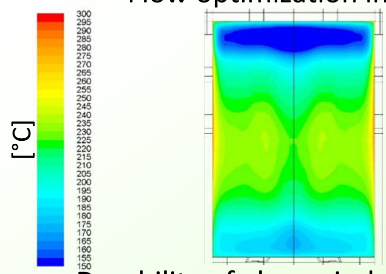
- **Wood log fired stoves and stove inserts**
- **Pellet fired stoves**

Special aspects

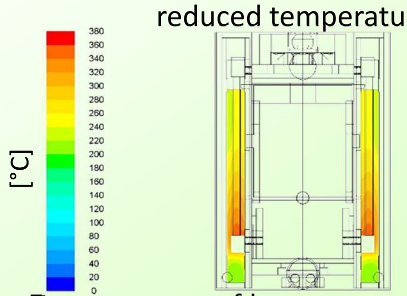
- Optimization of glass window regarding material durability, air flushing und fouling
- Achievement of complete burnout and minimal particulate matter emissions due to optimized geometry and mixing with air
- Optimization of efficiency
- Design of wood log fired stoves with heat storage



Flow optimization in stoves



Durability of glass window due to reduced temperatures



Temperatures of heat storage material

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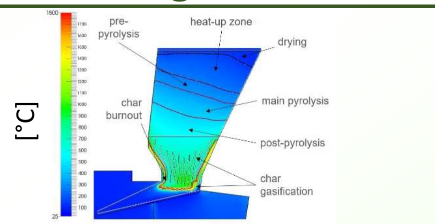
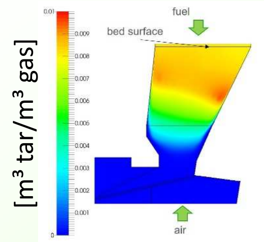
Working fields: CFD-based development and optimization of biomass fixed bed gasifiers and gas burners

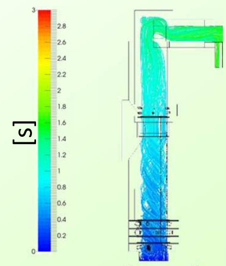
- **Development and optimization of reactor geometry**
  - Simulation of fixed bed and gas phase conversion based on 2D or 3D bed models for reactor optimization
  - Optimization of gasification and producer gas quality
  - Optimization of tar reduction
- **Development und optimization of producer gas burners**
  - Application of specially developed gas phase combustion models including tar conversion
  - Reduction of emissions
  - Optimization of efficiency



Gas temperatures – counter current fixed bed gasifier (CCFBG)



Tar concentrations - (CCFBG)



Optimization of residence time producer gas burner

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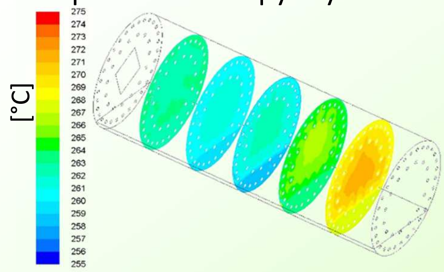
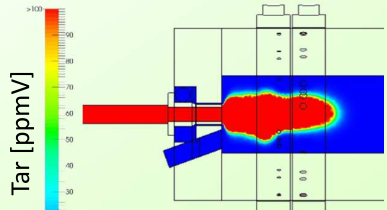
Working fields: CFD-based development of biomass fixed-bed pyrolysis and torrefaction plants

- **Development and optimization of reactor technology**
  - Simulation of fixed bed and gas phase conversion based on 2D or 3D bed models
  - Optimization of biochar quality and overall efficiency
- **Development and optimization of pyrolysis gas burners**
  - Avoidance of tar condensation
  - Optimization of tar reduction
  - Minimization of emissions

Optimization of pyrolysis reactor



Optimization of torrefaction reactor



Pyrolysis gas burner – tar reduction

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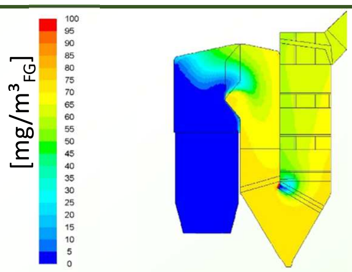
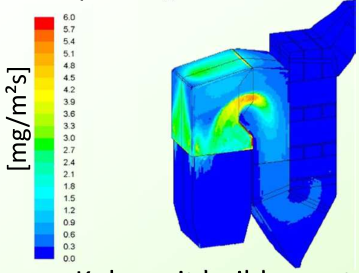
Working fields: CFD simulations concerning ash related issues

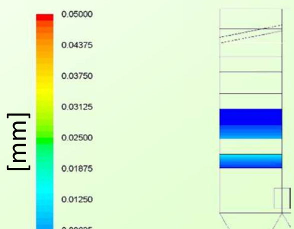
- **Simulations of ash deposit and aerosol formation**
  - Release model for coarse fly ash and ash vapours
  - Deposition of coarse fly ash particles on walls
  - Condensation of ash vapours
  - Consideration of erosion processes
  - Consideration of aerosol formation
  - Deposit built-up under consideration of the impact on heat flow
  - Calculation of ash precipitation rates in various plant regions
- **Simulations of corrosion**
  - Based on deposit formation simulations
  - Qualitative evaluation of local corrosion mechanisms (oxidation, scaling of steel, active chlorine induced oxidation, corrosion by molten salts)



K-sulphate (particulate matter)



K deposit build-up rate



Tube wall reduction by corrosion

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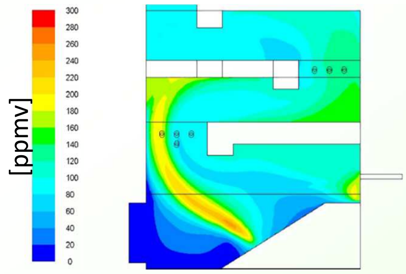
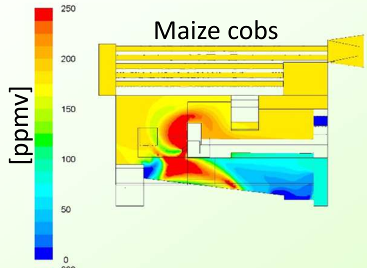
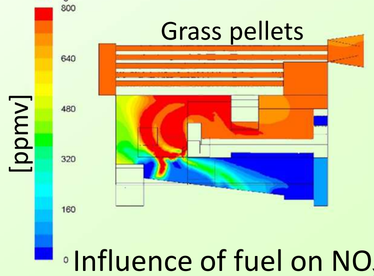
Working fields: CFD simulations of NO_x formation

- **Model overview**
  - Consideration of the relevant NO_x precursor species NO, NH_3 and HCN
  - Consideration of N release from fuel beds
  - Consideration of N release from tars
  - Realistic description of NO_x formation and reduction based on detailed kinetic mechanisms
  - Detailed, complete kinetics (Kilpinen 92) and reduced kinetics mechanism (Kilpinen 97-Skeletal) available
  - Eddy Dissipation Concept
- **Optimization of NO_x emission reduction by primary measures (e.g. air staging, optimization of residence time and mixing in the reduction zone)**



NO_x reduction optimization by air staging





Influence of fuel on NO_x

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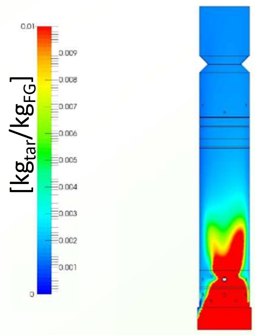
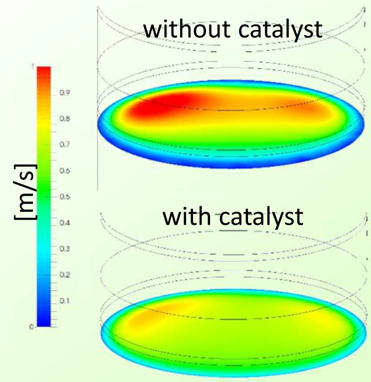
Working fields: CFD simulations of tar formation and tar conversion as well as integration of catalysts

- **Tar conversion model – model overview**
  - In-house developed detailed mechanism for the prediction of tar formation and tar conversion
  - Consideration of 37 species and 415 chemical reactions
  - Application for gas phase combustion simulations as well as bed simulations for pyrolysis and gasification
  - Optimization of tar burnout by primary measures
- **Catalyst model**
  - In-house developed model
  - Consideration of radiation interaction between gas and catalyst, convective heat transfer as well as anisotropic heat conduction in catalyst material
  - CFD based integration of catalysts in biomass conversion plants



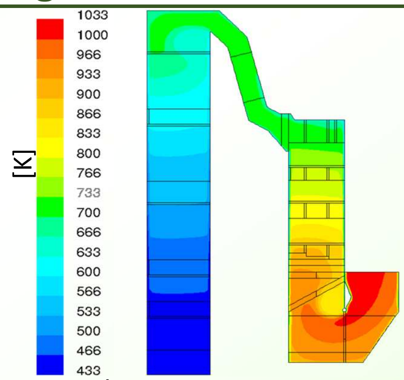
Tar reduction in producer gas burner



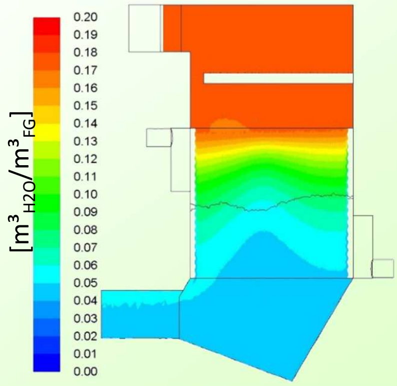
Influence of catalyst on flue gas velocities before catalyst

Working fields: Simulation of heat exchangers and condensers

- **Conventional heat exchangers**
  - Detailed simulation with explicitly resolved heat exchanger tubes
    - Application to small and medium-scale heat exchangers (high computational demand)
  - Simulation using in-house developed heat exchanger model
    - Application to tube bundle heat exchangers in large-scale combustion plants (lower computational demand)
- **Condensers**
  - Consideration of single heat exchanger tubes
  - DPM (Discrete Phase Model) based wall film condensation model considering the partial re-evaporation of the wall film
- **Consideration of primary and secondary heat transfer media (e.g. flue gas and water)**



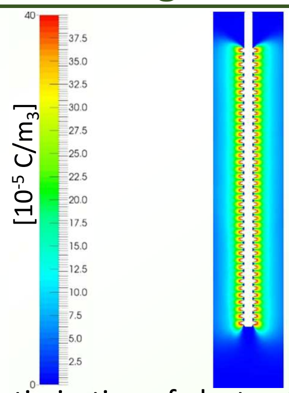
Flue gas temperatures in water tube steam boiler



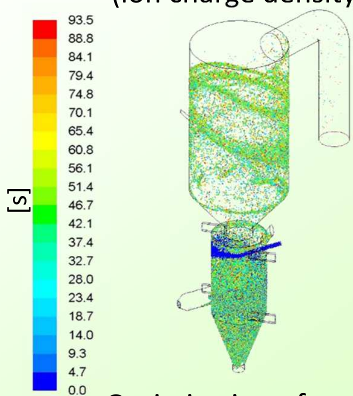
Water content in exhaust gas of condenser

Working fields: CFD simulations of gas cleaning units

- **Development and optimization of gas cleaning units for flue gas, producer gas and pyrolysis gas**
- **Development and optimization of:**
  - Electrostatic precipitators
  - Cyclones
  - Bag house filter
- **Optimization of:**
  - Flow
  - Residence time
  - Temperature distribution
  - Precipitation efficiency



Optimization of electrostatic precipitators (ion charge density)



Optimization of cyclones (particle residence times)

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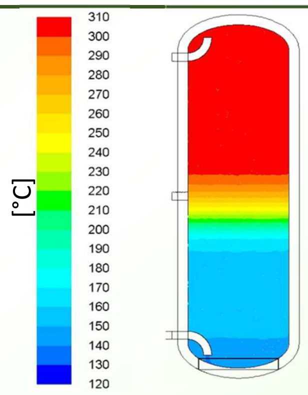
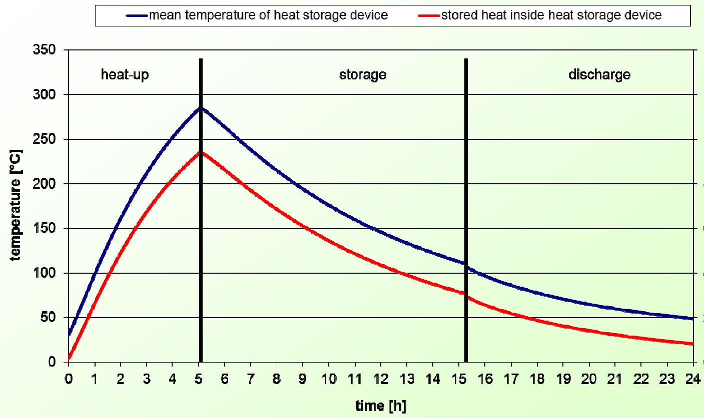
Working fields: CFD simulations of heat storage tanks

- **Development and optimization of buffer storage tanks, solid material storage systems and latent heat storage systems**
- **Transient CFD simulations for the evaluation of charging and discharging processes**
- **Optimization of:**
  - Layering behaviour
  - Required storage capacity
  - Heating and discharging cycles
  - Maximum temperatures (regarding allowed material temperatures)



Layers in a buffer storage tank



Charging and discharging - solid material storage

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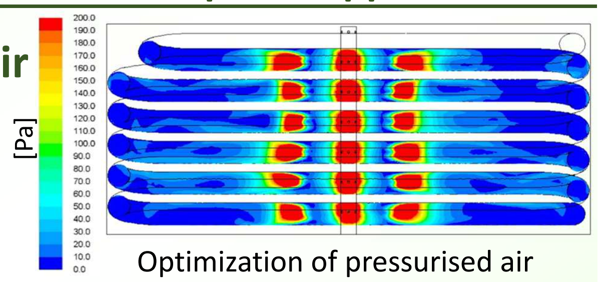
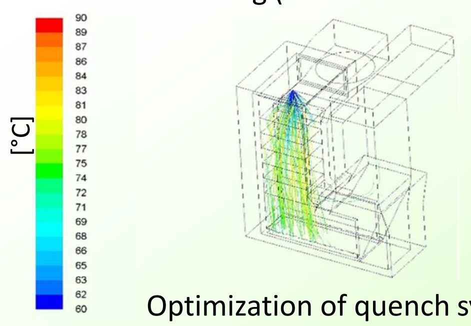
Working fields: CFD simulations for special applications

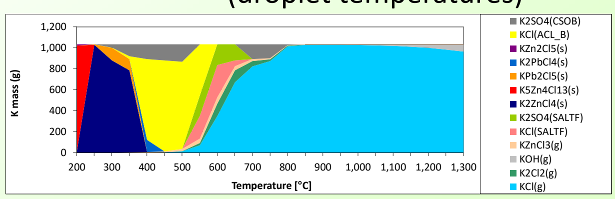
- **Evaluation and optimization of a pressurised air cleaning units**
- **Calculation of heat and pressure losses in pipe networks**
- **Flow simulations inside and outside of boiler houses and industrial plants**
- **Design and optimisation of mixing chambers (e.g. quench systems)**
- **Simulation of melting reactors**
- **Detailed kinetic calculations**
- **High-temperature equilibrium calculations (HT-EC) for the evaluation of ash chemistry**



Optimization of pressurised air cleaning (wall shear stress)



Optimization of quench system (droplet temperatures)



High temperature equilibrium calculations

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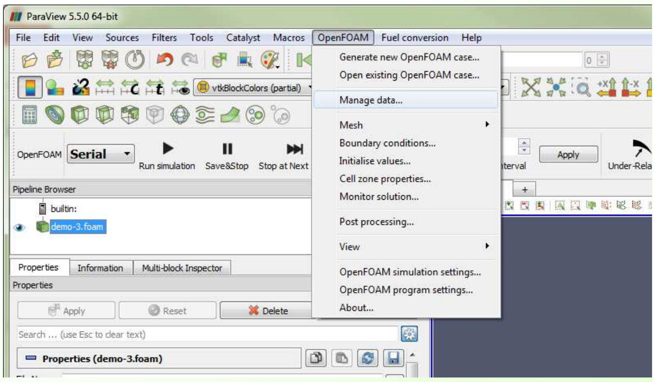
Working fields: Customised CFD simulation tools for clients based on OpenFOAM

- **The software package OpenBioPD (Open-Source-Software based Bioenergy Plant Design) of BIOS provides a customised CFD simulation tool for clients based on OpenFOAM.**
- **OpenBioPD is an efficient CFD based development tool for clients who want to perform CFD simulations by themselves.**
- **Advantages for clients:**
  - In-house developed CFD routines based on comprehensive experience of BIOS
  - Customised CFD routines tailored to the specific requirements of clients
  - In-house developed graphical user interface (GUI) tailored to the specific requirements of clients
  - Customer oriented training, support and update services.
  - No limitation regarding CPU usage.
  - No annual license fees.
- **OpenBioPD is a user-friendly and an easy to learn CFD software package**



GUI

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Awards (1)

Scientific award:

- **Award for the best scientific activity in the section of “Biomass Production and Utilisation R&D – Combustion” at the 1st World Conference and Exhibition on Biomass for Energy and Industry, June 2000, Sevilla, Spain for the poster “CFD ANALYSIS OF AIR STAGING AND FLUE GAS RECIRCULATION IN BIOMASS GRATE FURNACES”**

FEMtech's female expert of the month March 2020:

- **Dr. Mag. Claudia Benesch, area manager in the CFD department at BIOS, has been awarded as the FEMtech's female expert of the month in March 2020 from the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)**

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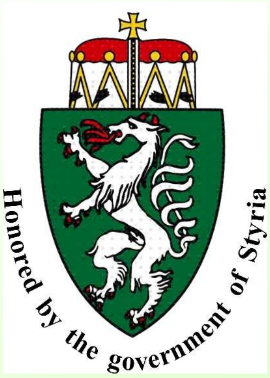
Awards (2)

Award for CFD-aided furnace development:

- Nomination for the special prize VERENA in the context of the Austrian national award Innovation 2015 „KWB Multifire – new boiler technology for the utilisation of agricultural residues“

Award of the Styrian Emblem:

- In recognition of its special performances in the interests of the province of Styria, the Styrian state government granted BIOS BIOENERGIESYSTEME GmbH the right to bear the provincial coat of arms in 2019.



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References (1)

- Development and optimisation of large-scale furnaces and boilers fired with biomass, waste wood and solid recovered fuels (boiler capacity > 1 MW_{th}) for industrial clients
  - Josef Bertsch GmbH & CO, Bludenz (AT)
  - TIWAG Tiroler Wasserkraft AG, Innsbruck (AT)
  - LINZ Strom GmbH, Linz (AT)
  - Standardkessel, Duisburg (DE)
  - Binder Energietechnik GmbH, Bärnbach (AT)
  - VYNCKE ENERGIETECHNIEK N.V., Harelbeke (BE)
  - Biostrom Erzeugungs GmbH, Fussach (AT)
  - VIESSMANN Holzfeuerungsanlagen GmbH, Hard (AT)
  - Euro Therm A/S, Tranbjerg (DK)
  - Oschatz GmbH, Essen (DE)
  - POLYTECHNIK Luft- und Feuerungstechnik GmbH, Weissenbach (AT)
  - Biomasse Italia S.p.A., Strongoli (IT)
  - TILLY HOLZINDUSTRIE GmbH, Treibach/Althofen (AT)
  - Wopfinger Baustoffindustrie GmbH, Waldegg (AT)
  - Andritz AG, Graz (AT)
  - MAWERA Holzfeuerungsanlagen GmbH, Hard (AT)

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References (2)

- **Development and optimisation of medium-scale furnaces (boiler capacity 0.1 – 11 MW_{th})**
  - VIESSMANN Holzfeuerungsanlagen GmbH, Hard (AT)
  - POLYTECHNIK Luft- und Feuerungstechnik GmbH, Weissenbach (AT)
  - UNICONFORT srl, San Martino di Lupari (IT)
  - KWB Kraft und Wärme aus Biomasse GmbH, St. Margarethen (AT)
  - SL-Technik GmbH, St. Pantaleon (AT)
- **Development and optimisation of small-scale furnaces and stoves (boiler capacity < 100 kW_{th})**
  - Viessmann Werke GmbH & Co KG, Allendorf (Eder) (DE)
  - KWB Kraft und Wärme aus Biomasse GmbH, St. Margarethen (AT)
  - Windhager Zentralheizung GmbH, Seekirchen (AT)
  - HAAS + SOHN OFENTECHNIK GMBH, Puch (AT)
  - Fröling Heizkessel- und Behälterbau GmbH, Grieskirchen (AT)
  - GUNTAMATIC Heiztechnik GmbH, Peuerbach (AT)

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References (3)

- **Development and optimisation of small-scale furnaces and stoves (boiler capacity < 100 kW_{th}) (continued)**
  - ETA Heiztechnik GmbH, Hofkirchen an der Trattnach (AT)
  - RIKA Innovative Ofentechnik GmbH, Micheldorf (AT)
  - SL-Technik GmbH, St. Pantaleon (AT)
- **Development and optimisation of gasification technologies and gas burners**
  - POLYTECHNIK Luft- und Feuerungstechnik GmbH, Weissenbach (AT)
  - Windhager Zentralheizung GmbH, Seekirchen (AT)
  - Viessmann Werke GmbH & Co KG, Allendorf (Eder) (DE)
  - MAWERA Holzfeuerungsanlagen GmbH, Hard (AT)
  - MWH Treatment Ltd, Manchester (UK)
- **Development and optimisation of pyrolysis plants and pyrolysis oil and gas burners**
  - POLYTECHNIK Luft- und Feuerungstechnik GmbH, Weissenbach (AT)
  - OPRA Turbines BV, Hengelo (NL)
  - Andritz AG, Graz (AT)

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References (4)

Further CFD activities:

- Development of electrostatic precipitators: Scheuch GmbH, Aurolzmünster (AT)
- Development of flue gas condensers, SL-Technik GmbH, Kelvion GmbH (AT)
- Heat loss calculations of district heating tubes: A/S Star Pipe, Fredericia (DK)
- Optimisation of post combustion in a dust precipitation chamber, Taiwan Steel Union CO., LTD (TW)
- Optimisation of a pressurised air cleaning unit in a biomass-fired small-scale boiler plant, ETA Heiztechnik GmbH, Hofkirchen an der Trattnach (AT)
- Pressure loss calculations of a tube elbow, ISOPLUS Fernwärmetechnik GmbH, Hohenberg (AT)
- Simulation of charging and discharging of a thermic oil buffer storage tank, voestalpine Tubulars GmbH & Co KG, Kindberg-Aumuehl (AT)
- Simulation of the flow outside an air cooling unit, EVN AG, Maria Enzersdorf (AT)

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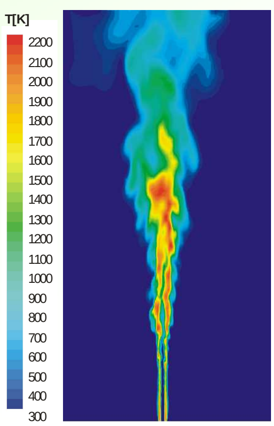
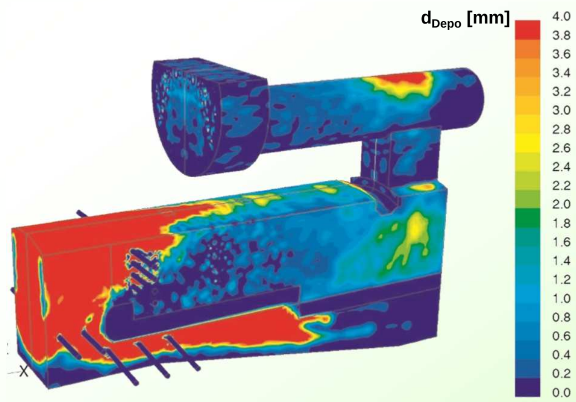
Your partner for energy utilisation from biomass and energy efficiency
Research • Development • Engineering

CFD simulations

in the field of thermal biomass conversion

Advantages – Fields of application – Innovations





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