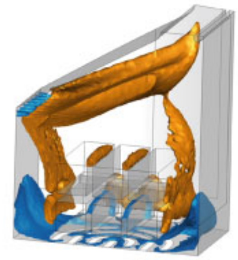
WoodCFD

Clean and efficient wood stoves through improved batch combustion models and CFD modelling approaches



Newsletter 2-2018

Introduction

The WoodCFD project is proceeding as planned, focusing on achieving the overall objective, which is development of clean and efficient wood stoves through improved batch combustion models and CFD modelling approaches through:

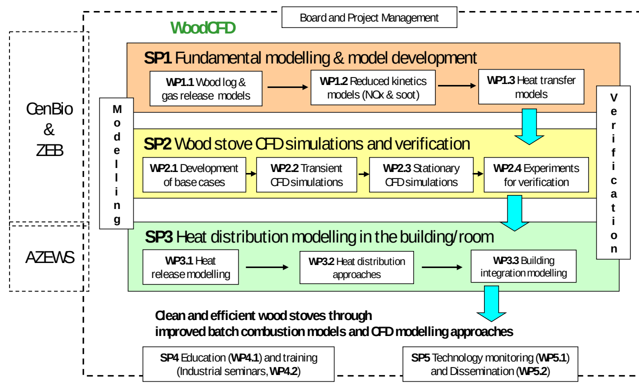
- Model development: improved transient wood log and gas release models, transient heat transfer and storage models, reduced kinetics models (NOx and soot), and transient models and approaches for heat distribution in the building; and verification of these
- Simulations: transient and stationary CFD simulations of wood stoves, and room and building integration simulations; and verification of these

The sub-objectives are:

- Develop improved sub models to be included in the CFD simulations
- Develop a numerical tool that is suitable to study concept improvements for wood stoves and to recommend new improved concepts with respect to high energy efficiency and low emissions based on simulation results
- Develop improved transient heat distribution models - giving reliable prediction of the effect of various heat transfer concepts in buildings and providing design guidelines for optimum wood stoves for tomorrows (energy efficient) buildings
- Education of highly skilled candidates within this area and training of industry partners
- Monitoring of activities and state-of-the-art within this area and dissemination of knowledge to the industry partners, and other interested parties when applicable

The anticipated results of the project are clean and efficient wood stoves through improved batch combustion models and CFD modelling approaches. Improved models and modelling approaches, in combination with targeted experiments, are keys in the development of future's downscaled clean burning and energy efficient wood stoves. This will have a potentially huge impact on the most important bioenergy value chain in Norway today, targeting key bottlenecks in the value chain, i.e. reducing today's still relatively high emissions from wood stoves and improving their energy efficiency, especially in low load wood stoves, as well as ensuring optimum room and building integration.

The Work Breakdown Structure of WoodCFD is:



WoodCFD will run for four years (2015-2018) and has a total budget of 17.5 million NOK which is 80% financed by the Research Council of Norway through the ENERGIX program and 20% financed by the industrial partners Jøtul AS, Dovre AS, Norsk Kleber AS, Morsø A/S.

Progress in 2018

In **2018**, det final year of WoodCFD, the focus has been on transient CFD simulations with heat storage, wood stove optimization, NOx reduction and building integration via dynamic and CFD simulations. A handbook has been made that sums up the project and gives recommendations.

- a Knowledge-building Project for Industry (KPN) co-funded by
the Research Council of Norway through the ENERGIX-programme.
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SINTEF

In **2017** the work focused on testing and use of developed sub-models in CFD simulations, and the PhD candidate focused on further development of the decomposition model for wood logs, and has now several publications on this. The thermal comfort work in 2017 focused on experimental activity to provide detailed data for further development and validation of models.
The work with the sub-models, also for stationary CFD simulations, was continued in **2016**. The employed PhD candidate in the project focus on development of a thermal decomposition model for wood logs. In parallel work was ongoing regarding improvement of models and tools used for simulation of thermal comfort in energy effective buildings with wood stoves.
In **2015** the scientific focus was on initial studies and establishment of sub-models for use in transient CFD simulations, as well as modelling of heat transfer in stoves and analysis of heat distribution to other rooms in a building.

WoodCFD at EUBCE 2019

Three WoodCFD or connected works have been accepted for presentation at EUBCE 2019 in Lisbon, Portugal, 27-30 May 2019:
1) Øyvind Skreiberg, Nils E. L. Haugen, Mette Bugge, Laurent Georges. CFD and building integration modelling of wood stoves - Status and further needs.
2) Øyvind Skreiberg, Mette Bugge, Tian Li, Nils E. L. Haugen. Assessment of NOx reduction potential in wood stoves.
3) Alexis Sevault, Henning Hvål Mathisen, Erling Næss, Øyvind Skreiberg. Integrating PCM-based thermal energy storage on top of wood stoves: concept and CFD modelling. Co-presentation with PCM-Eff.

WoodCFD at ICheaP14

Two WoodCFD works have been accepted for presentation at ICheaP14 in Bologna, Italy, 26-29 May 2019:
1) Mette Bugge, Nils E. L. Haugen, Øyvind Skreiberg. Transient CFD simulations of wood stoves with varying heat storage capacity.
2) Mette Bugge, Nils E. L. Haugen, Morten Seljeskog, Øyvind Skreiberg. Wood log combustion hysteresis demonstrated through transient CFD simulations and experiments.

WoodCFD at CLIMA 2019

One WoodCFD work has been accepted for presentation at CLIMA 2019 in Bucharest, Romania, 26-29 May 2019:
Martin Thalfeldt, Laurent Georges, Øyvind Skreiberg. A Simplified Power Sizing Method for the Correct Building Integration of Wood Stoves.

WoodCFD in EERA Bioenergy News

Two articles entitled "Numerical simulation of the transient behavior of wood log decomposition and combustion" and "Investigation of the detailed indoor thermal environment of buildings heated using wood stoves" were included in the December 2018 edition of the EERA Bioenergy newsletter.

WoodCFD at IBPSA Nordic workshop

One WoodCFD work was presented at IBPSA Nordic / NORVAC 2018 workshop at VVS-dagene 2018, 17-19 October, Lillestrøm, Norway:
Laurent Georges, Martin Thalfeldt, Øyvind Skreiberg, Walter Fornari. Zonal model to predict the detailed indoor environment - Case of electric radiators and wood stoves.

WoodCFD at IConBM 2018

Three WoodCFD or connected works were presented at IConBM 2018 in Bologna, Italy, 17-20 June 2018:
1) Øyvind Skreiberg, Morten Seljeskog. Performance history and further improvement potential for wood stoves.

2) Øyvind Skreiberg, Laurent Georges. Transient heat production profiles for wood log combustion in wood stoves.
3) Alexis Sevault, Jerol Soibam, Nils Erland L. Haugen, Øyvind Skreiberg. Investigation of an Innovative Latent Heat Storage Concept in a Stovepipe. Co-presentation with PCM-Eff.
Corresponding full papers have been published in Chemical Engineering Transactions.

WoodCFD at RoomVent 2018

Two WoodCFD works were presented at RoomVent 2018 in Espoo, Finland, 2-5 June 2018:
1) Laurent Georges, Martin Thalfeldt, Øyvind Skreiberg, Per Sahlin, Patrik Skogqvist. Validation of an unsteady zonal model to capture the thermal stratification in a room heated by a stove.
2) Martin Thalfeldt, Laurent Georges, Øyvind Skreiberg. Characterization of the free plume created by stoves using laboratory measurements.
Corresponding full papers have been published in the conference proceedings.

WoodCFD at EUBCE 2018

Two WoodCFD or connected works were presented at EUBCE 2018 in Copenhagen, Denmark, 14-17 May 2018:
1) Mette Bugge, Nils E. L. Haugen, Morten Seljeskog, Øyvind Skreiberg. Hysteresis in wood log combustion, demonstrated through transient CFD simulations and experiments.
2) Alexis Sevault, Nils Erland L. Haugen, Øyvind Skreiberg. A comparison of selected latent heat storage configurations for wood stoves. Co-presentation with PCM-Eff.

WoodCFD at 14th International Conference on Energy Storage

One WoodCFD connected work was presented at 14th International Conference on Energy Storage, 25-28 April 2018, Adana, Turkey:
Alexis Sevault, Jerol Soibam, Nils Erland L. Haugen, Øyvind Skreiberg. Numerical modeling of a latent heat storage system in a stovepipe. Co-presentation with PCM-Eff.
A corresponding full paper has been published in the conference proceedings.

WoodCFD at Cold Climate HVAC 2018

Two WoodCFD works were presented at Cold Climate HVAC 2018 in Kiruna, Sweden, 12-15 March 2018:
1) Martin Thalfeldt, Laurent Georges, Øyvind Skreiberg. Validation of a zonal model to capture the detailed indoor thermal environment of a room heated by a wood stove.
2) Mathieu Hamon, Guangyu Cao, Øyvind Skreiberg, Laurent Georges, Morten Seljeskog, Roger Khalil, Alexis Sevault, Hans Martin Mathisen. Assessment of the effects of using wood stoves on indoor air quality in two types of Norwegian houses.
Corresponding full papers will be published in Springer Proceedings in Energy.

WoodCFD in Building and Environment

A work entitled "Validation of a transient zonal model to predict the detailed indoor thermal environment: case of electric radiators and wood stoves" has been published in Building and Environment. The abstract is given below.

"In building performance simulation (BPS), zonal models are intermediate models between standard models assuming perfectly-mixed room air and Computational Fluid Dynamics (CFD): they aim to predict the air temperature and velocity fields as well as the pollutant distribution inside a room using a computational time significantly lower than using CFD. The article aims at validating a transient zonal model that is currently implemented in the commercial BPS tool, IDA ICE. In theory, this one-dimensional model can address a large variety of airflows and requires almost no a priori knowledge of the flow to be computed. The model is validated against measurements in a laboratory heated by either electric radiators or an electric stove designed to mimic surface temperatures of real stoves. Unlike radiators, the case of stoves has never been addressed in the literature and is challenging due to the strong thermal coupling between the room air and walls. Heat emitters have been placed either in the middle of the room or along walls. The zonal model remarkably well predicts the time evolution of the air temperature stratification in the room for all test cases. For a heat emitter in a central position, the wall surface temperatures are predicted correctly. Nevertheless, for a heat emitter along walls, these walls cannot be considered isothermal anymore, an assumption found in most BPS tools. The paper suggests that an automatized method to divide walls in the vicinity of heat emitters is necessary for a reliable prediction of the wall surface temperatures."

WoodCFD in Energy & Fuels

The WoodCFD PhD candidate published her 4th major work entitled "Simulating thermal wood particle conversion: Ash-layer modeling and parametric studies" in Energy & Fuels. The abstract is given below.

"In this work, we study the thermochemical degradation and char conversion of wet wood particles. The work is split in two main parts: (1) the effect of the ash layer handling approach and (2) a parametric study over different relevant parameters. In the study of the ash layer handling, we investigate the effect of allowing the ash to remain on the surface of the particle when the char is converted (Model A), in contrast to removing the ash such that the reacting char layer is always exposed (Model B). It was found that the two modeling concepts yield significantly different mass losses and surface and center temperature predictions. Model B presents a faster thermal conversion, while the results predicted by Model A are in better agreement with what has been observed experimentally. A parametric study was also done, where the sensitivity to variations in thermal conductivity, specific surface area, and gas permeability was studied. It was found that thermal conductivity influences the time when drying and devolatilization are accomplished. This is because these conversion stages are heat-transfer-controlled. Char conversion is primarily affected by a shift to earlier times for the initialization of the final char conversion when higher thermal conductivities are used. It is found that the specific surface area smaller than a critical value can significantly affect the final char conversion time. Since char conversion is a key stage of wood combustion, the full conversion time is also affected. The gas permeability primarily affects mass diffusion into the particle. It was found that, up until a critical effective gas permeability, the modeling results are sensitive to assigned permeabilities."

WoodCFD in Energy & Fuels

The WoodCFD PhD candidate published her 3rd major work entitled "Combustion of thermally thick wood particles: A study on the influence of wood particle size on the combustion behavior" in Energy & Fuels. The abstract is given below.

"A one-dimensional (1D) comprehensive combustion model for thermally thick wet wood particles, which is also applicable for studying large wood logs, is developed. The model describes drying, devolatilization, and char gasification as well as char oxidation. Furthermore, CO oxidation is modeled, in order to account for the fact that exiting gas products can be oxidized and therefore limit the oxygen transportation to the active sites. The challenges for model validation are outlined. Model validation was done against experimental data for combustion of near-spherical wood particles. Furthermore, the validated model was up-scaled and the effect of wood log diameter on the thermal conversion time, the extent as well as the position of drying, devolatilization, and char conversion zones were studied. The upscaling was done for cylindrical wood logs with an aspect ratio of 4. The thermal conversion time significantly increased with the size. It was also found that the relative extent of the drying, devolatilization, and char conversion zones decreased as wood log size increased. The paper concludes with recommendations for future work."

WoodCFD in Scientific Reports

A WoodCFD connected work entitled "Cooling aerosols and changes in albedo counteract warming from CO_2 and black carbon from forest bioenergy in Norway" was published in Scientific Reports. The abstract is given below.

"Climate impacts of forest bioenergy result from a multitude of warming and cooling effects and vary by location and technology. While past bioenergy studies have analysed a limited number of climate-altering pollutants and activities, no studies have jointly addressed supply chain greenhouse gas emissions, biogenic CO_2 fluxes, aerosols and albedo changes at high spatial and process detail. Here, we present a national-level climate impact analysis of stationary bioenergy systems in Norway based on wood-burning stoves and wood biomass-based district heating. We find that cooling aerosols and albedo offset 60–70% of total warming, leaving a net warming of 340 or 69 kg CO_2e MWh^{-1} for stoves or district heating, respectively. Large variations are observed over locations for albedo, and over technology alternatives for aerosols. By demonstrating both notable magnitudes and complexities of different climate warming and cooling effects of forest bioenergy in Norway, our study emphasizes the need to consider multiple forcing agents in climate impact analysis of forest bioenergy."

WoodCFD blog article

A blog article entitled "Drying firewood logs – just how dry can a research topic get?" related to the PhD candidate work has been published by SINTEF Energy Research.
Norwegian version: Tørking av vedkubber – Hvor tørt kan et forskningstema egentlig bli?

WoodCFD in Energy & Fuels

The WoodCFD PhD candidate published her 2nd major work entitled "Drying of thermally thick wood particles: A study of the numerical efficiency, accuracy and stability of common drying models" in Energy & Fuels. The abstract is given below.

"The primary focus of this paper is on studying different numerical models for drying wet wood. More specifically, the advantages and disadvantages of the models, with respect to numerical efficiency, stability, and accuracy, are investigated. The two basic models that are studied in detail are the thermal drying model and the kinetic rate drying model. The drying models have been implemented in an in-house simulation tool that solves for drying and devolatilization of a one-dimensional cylindrical wood log. It is found that the choice of drying model can significantly influence the computational time associated with the thermal conversion. Furthermore, the occurrence of numerical pressure oscillations in the thermal drying model has been found and investigated. The numerical oscillations are reduced by introducing an evaporation fraction, f_{evap}. When the thermal drying model is applied, the drying zone is very thin, commonly only including one grid point, which can result in numerical instabilities. The evaporation fraction allows the smearing of the drying zone by reducing the heat flux used for evaporation of liquid water and using the residual heat flux for heating the grid points. Reducing the evaporation fraction also resulted in reduced CPU times. It was found that model accuracy was not significantly influenced by the choice of drying model."

WoodCFD in EERA Bioenergy News

An article entitled "Computational Fluid Dynamics for improving micro- to large-scale woody biomass and municipal solid waste combustion units" presented WoodCFD and also GrateCFD (Enabling optimum Grate fired woody biomass and waste to energy plant operation through Computational Fluid Dynamics) in an EERA Bioenergy newsletter.

WoodCFD in Progress in Energy and Combustion Science

A comprehensive review paper with the WoodCFD PhD candidate Inge Haberle as first author has been published in Progress in Energy and Combustion Science:

Inge Haberle, Øyvind Skreiberg, Joanna Lazar, Nils Erland L. Haugen. Numerical models for thermochemical degradation of thermally thick woody biomass, and their application in domestic wood heating appliances and grate furnaces. Progress in Energy and Combustion Science 63(November 2017):204-252. The abstract is given below.

"This paper reviews the current state-of-the-art of numerical models used for thermochemical degradation and combustion of thermally thick woody biomass particles. The focus is on the theory of drying, devolatilization and char conversion with respect to their implementation in numerical simulation tools. An introduction to wood chemistry, as well as the physical characteristics of wood, is also given in order to facilitate the discussion of simplifying assumptions in current models. Current research on single, densified or non-compressed, wood particle modeling is presented, and modeling approaches are compared. The different modeling approaches are categorized by the dimensionality of the model (1D, 2D or 3D), and the one-dimensional models are separated into mesh-based and interface-based models. Additionally, the applicability of the models for wood stoves is discussed, and an overview of the existing literature on numerical simulations of small-scale wood stoves and domestic boilers is given. Furthermore, current bed modeling approaches in large-scale grate furnaces are presented and compared against single particle models."

WoodCFD at ICAE 2017. Papers now published in Energy Procedia

Three WoodCFD or connected works were presented at the 9th International Conference on Applied Energy in Cardiff, UK, 21-24 August 2017:

1) Øyvind Skreiberg, Laurent Georges. Wood stove material configurations for increased thermal comfort.

2) Inge Haberle, Nils Erland L. Haugen, Øyvind Skreiberg. Comparison of numerical efficiency of the thermal and the kinetic rate drying model applied to a thermally thick wood particle.

3) Alexis Sevault, Roger Khalil, Bjørn Christian Enger, Øyvind Skreiberg, Franziska Goile, Liang Wang, Morten Seljeskog, Rajesh Kempegowda. Performance evaluation of a modern wood stove using charcoal.

These works have now been published in Energy Procedia.

WoodCFD at 25th European Biomass Conference & Exhibition

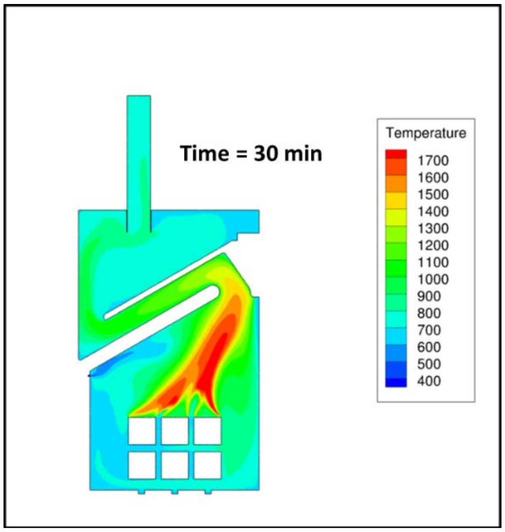
Four WoodCFD or connected works were presented at the 25th EUBCE conference in Stockholm, Sweden, 12-15 June 2017:

1) Mette Bugge, Nils E. L. Haugen, Øyvind Skreiberg. Transient CFD simulations of wood log combustion in a wood stove.

2) Inge Haberle, Øyvind Skreiberg, Nils Erland L. Haugen. Numerical simulation of devolatilization of wood logs and pressure generation in the wood log center. Published in proceedings, pp. 561-565.

3) Alexis Sevault, Roger Khalil, Bjørn Christian Enger, Øyvind Skreiberg, Franziska Goile, Liang Wang, Morten Seljeskog, Rajesh Kempegowda. Performance evaluation of a modern wood stove when using charcoal.

4) A. Cablé, L. Georges, P. Peigné, Ø. Skreiberg, K. Chetehouna. Coupled ventilation system and wood logs-stove for use in low energy dwellings: an investigation using dynamic energy simulations. Published in proceedings, pp. 611-617.



Transient CFD simulations of wood log combustion

WoodCFD at CenBio Final Conference

Øyvind Skreiberg gave a presentation at the CenBio Final Conference in Ås, Norway, 13-14 March 2017. The title of the presentation was "The ultimate wood stove".

WoodCFD at ICAE 2016. Papers now published in Energy Procedia

WoodCFD related work was presented at the 8th International Conference on Applied Energy in Beijing, China, 8-11 October 2016. Two papers were presented by Morten Seljeskog, with the titles "Variables affecting emission measurements from domestic wood combustion" and "Recommended revisions of Norwegian emission factors for wood stoves". The papers have now been published in Energy Procedia.

PhD work - PhD thesis defended

The PhD work "Numerical simulation of transient behavior of wood log decomposition and combustion" is now finalized. The candidate, Inge Haberle from Austria, has had very good progress in her research work, focusing on modelling of the thermal decomposition of thermally thick biomass particles. A number of publications have resulted from her work. The PhD thesis has been finalized and the PhD defense was arranged 27 November, in Trondheim. Inge Haberle defended her thesis excellently. In connection with the defense, she also gave a trial lecture entitled "100% renewable energy for heating and cooling of buildings not connected to district heating networks in Europe in 2050 – technology options and the potential role of wood stoves".

Postdoc work - Finalized

The two-year postdoc work connected to the building integration work has now been finalized. The postdoc candidate has been Martin Thalfeldt from Estonia.

Master, project and summer students

During the four years of WoodCFD, Several Master students have also been connected to WoodCFD, contributing to different topics through a specialisation project or a Master thesis. In addition, a summer job student has been financed by WoodCFD, through the annual SINTEF summer job project. The combined contribution from the students has been invaluable for the project, making it possible to achieve more within the given budget.

WoodCFD publications

Øyvind Skreiberg, Nils E. L. Haugen, Mette Bugge, Laurent Georges. CFD and building integration modelling of wood stoves - Status and further needs. Accepted for presentation at 27th European Biomass Conference & Exhibition (**EUBCE**), 27-30 May 2019, Lisbon, Portugal.

Øyvind Skreiberg, Mette Bugge, Tian Li, Nils E. L. Haugen. Assessment of NOx reduction potential in wood stoves. Accepted for presentation at 27th EUBCE.

Alexis Sevault, Henning Hvål Mathisen, Erling Næss, Øyvind Skreiberg. Integrating PCM-based thermal energy storage on top of wood stoves: concept and CFD modelling. Accepted for presentation at 27th EUBCE. Co-presentation with PCM-Eff.

Mette Bugge, Nils E. L. Haugen, Øyvind Skreiberg. Transient CFD simulations of wood stoves with varying heat storage capacity. Abstract accepted for presentation at ICheaP14, 26-29 May 2019, Bologna, Italy.

Mette Bugge, Nils E. L. Haugen, Morten Seljeskog, Øyvind Skreiberg. Wood log combustion hysteresis demonstrated through transient CFD simulations and experiments. Abstract accepted for presentation at ICheaP14, 26-29 May 2019, Bologna, Italy.

Martin Thalfeldt, Laurent Georges, Øyvind Skreiberg. A Simplified Power Sizing Method for the Correct Building Integration of Wood Stoves. Abstract accepted for presentation at CLIMA 2019, 26-29 May 2019, Bucharest, Romania.

Laurent Georges, Øyvind Skreiberg (2018). Investigation of the detailed indoor thermal environment of buildings heated using wood stoves. EERA Bioenergy December 2018 newsletter.

Nils Erland L. Haugen, Inge Haberle, Øyvind Skreiberg (2018). Numerical simulation of the transient behavior of wood log decomposition and combustion. EERA Bioenergy December 2018 newsletter.

Inge Haberle, Nils E. L. Haugen, Øyvind Skreiberg. Thermal conversion of large wood particles. Abstract submitted to 17th International Conference on Numerical Combustion, 6-8 May 2019, Aachen, Germany.

Alexis Sevault, Henning Hvål Mathisen, Erling Næss, Øyvind Skreiberg. Latent heat storage unit integrated on top of wood stoves: concept design and preliminary modelling approach. Abstract submitted to Eurotherm Seminar #112 Advances in Thermal Energy Storage, 15-17 May 2019, Lleida, Spain. For co-presentation with PCM-Eff.

Laurent Georges, Martin Thalfeldt, Øyvind Skreiberg, Walter Fornari (2019). Validation of a transient zonal model to predict the detailed indoor thermal environment: case of electric radiators and wood stoves. Building and Environment 149:169-181.

Inge Haberle (2018). 100% renewable energy for heating and cooling of buildings not connected to district heating networks in Europe in 2050 – technology options and the potential role of wood stoves. Trial lecture.

Inge Haberle. Numerical simulation of transient behavior of wood log decomposition and combustion. PhD thesis 2018:280, NTNU. Main supervisor: Nils Erland L. Haugen, Co-supervisor: Øyvind Skreiberg

Laurent Georges, Martin Thalfeldt, Øyvind Skreiberg, Walter Fornari (2018). Zonal model to predict the detailed indoor environment - Case of electric radiators and wood stoves. IBPSA Nordic / NORVAC 2018 workshop at VVS-dagene 2018, 17-19 October, Lillestrøm, Norway.

Inge Haberle, Nils Erland L. Haugen, Øyvind Skreiberg (2018). Simulating thermal wood particle conversion: Ash-layer modeling and parametric studies. Energy & Fuels 32:10668-10682.

Anders Skare (2018). Validation of a method to select the optimal nominal power of a wood stove in residential buildings. NTNU Master thesis. Main supervisor: Laurent Georges, Co-supervisors: Martin Thalfeldt, Øyvind Skreiberg

Inge Haberle, Nils Erland L. Haugen, Øyvind Skreiberg (2018). Combustion of thermally thick wood particles: A study on the influence of wood particle size on the combustion behavior. Energy & Fuels 32(6):6847-6862.

Øyvind Skreiberg, Morten Seljeskog (2018). Performance history and further improvement potential for wood stoves. Chemical Engineering Transactions 65:199-204.

Øyvind Skreiberg, Laurent Georges (2018). Transient heat production and release profiles for wood stoves. Chemical Engineering Transactions 65:223-228.

Alexis Sevault, Jerol Soibam, Nils Erland L. Haugen, Øyvind Skreiberg (2018). Investigation of an Innovative Latent Heat Storage Concept in a Stovepipe. Chemical Engineering Transactions 65:25-30. Co-publication with PCM-Eff.

Laurent Georges, Martin Thalfeldt, Øyvind Skreiberg, Per Sahlin, Patrik Skogqvist (2018). Validation of a zonal model to capture the thermal stratification in a room heated by a stove. Proceedings of RoomVent 2018, 2-5 June 2018, Espoo, Finland, pp. 511-516.

Martin Thalfeldt, Laurent Georges, Øyvind Skreiberg (2018). Characterization of the free plume created by stoves using laboratory measurements. Proceedings of RoomVent 2018, 2-5 June 2018, Espoo, Finland, pp. 505-510.

Mette Bugge, Nils Erland L. Haugen, Morten Seljeskog, Øyvind Skreiberg (2018). Hysteresis in wood log combustion, demonstrated through transient CFD simulations and experiments. 26th European Biomass Conference & Exhibition (**EUBCE**), 14-17 May 2018, Copenhagen, Denmark.

Alexis Sevault, Nils Erland L. Haugen, Øyvind Skreiberg (2018). A comparison of selected latent heat storage configurations for wood stoves 26th EUBCE. Co-presentation with PCM-Eff.

Alexis Sevault, Jerol Soibam, Nils Erland L. Haugen, Øyvind Skreiberg (2018). Numerical modeling of a latent heat storage system in a stovepipe. Proceedings of 14th International Conference on Energy Storage, 25-28 April 2018, Adana, Turkey, pp. 969-983. Co-publication with PCM-Eff.

Mathieu Hamon, Guangyu Cao, Øyvind Skreiberg, Laurent Georges, Morten Seljeskog, Roger Khalil, Alexis Sevault, Hans Martin Mathisen (2018). Assessment of the effects of using wood stoves on indoor air quality in two types of Norwegian houses. Cold Climate HVAC 2018, 12-15 March 2018, Kiruna, Sweden. Accepted for publication in Springer Proceedings in Energy.

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Anders Arvesen, Francesco Cherubini, Gonzalo del Alamo Serrano, Rasmus Astrup, Michael Becidan, Helmer Belbo, Franziska Goile, Tuva Grytli, Per Kristian Rørstad, Line Rydså, Morten Seljeskog, Øyvind Skreiberg, Sajith Vezhapparambu, Anders Hammer Strømman (2018). Cooling aerosols and changes in albedo counteract warming from CO_2 and black carbon from forest bioenergy in Norway. Scientific Reports 8, Article 3299.

Inge Haberle, Nils Erland L Haugen, Øyvind Skreiberg (2017). Drying of thermally thick wood particles: A study of the numerical efficiency, accuracy and stability of common drying models. Energy & Fuels 31(12):13743-13760.

Øyvind Skreiberg, Laurent Georges (2017). Wood stove material configurations for increased thermal comfort. Energy Procedia 142:488-494.

Inge Haberle, Nils Erland L. Haugen, Øyvind Skreiberg (2017). Comparison of numerical efficiency of the thermal and the kinetic rate drying model applied to a thermally thick wood particle. Energy Procedia 142:37-42.

Alexis Sevault, Roger Khalil, Bjørn Christian Enger, Øyvind Skreiberg, Franziska Goile, Liang Wang, Morten Seljeskog, Rajesh Kempegowda (2017). Performance evaluation of a modern wood stove using charcoal. Energy Procedia 142:192-197.

Anders Skare (2017). Evaluation method to select the optimal nominal power of a wood stove in residential buildings. NTNU Project thesis. Main supervisor: Laurent Georges, Co-supervisors: Martin Thalfeldt, Morten Seljeskog

Inge Haberle, Øyvind Skreiberg, Joanna Lazar, Nils Erland L. Haugen (2017). Numerical models for thermochemical degradation of thermally thick woody biomass, and their application in domestic wood heating appliances and grate furnaces. Progress in Energy and Combustion Science 63:204-252.

Øyvind Skreiberg (2017). Computational Fluid Dynamics for improving micro- to large-scale woody biomass and municipal solid waste combustion units. EERA Bioenergy News 2017 (7), p. 5.

Mette Bugge, Nils E. L. Haugen, Øyvind Skreiberg (2017). Transient CFD simulations of wood log combustion in a wood stove. 25th European Biomass Conference & Exhibition (**EUBCE**), 12-15 June 2017, Stockholm, Sweden.

Inge Haberle, Øyvind Skreiberg, Nils Erland L. Haugen (2017). Numerical simulation of devolatilization of wood logs and pressure generation in the wood log center. Proceedings of 25th EUBCE, pp. 561-565.

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A. Cablé, L. Georges, P. Peigné, Ø. Skreiberg, K. Chetehouna (2017). Coupled ventilation system and wood logs-stove for use in low energy dwellings: an investigation using dynamic energy simulations. Proceedings of 25th EUBCE, pp. 611-617.

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Øyvind Skreiberg. Drying firewood logs – just how dry can a research topic get? SINTEF Energy Research blog 23 January 2018.

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Øyvind Skreiberg, Morten Seljeskog, Laurent Georges (2015). Solutions and technologies for wood stoves in future's energy efficient residential buildings. Oral presentation at 23rd European Biomass Conference &

Exhibition (**EUBCE**), 1-4 June 2015, Vienna, Austria. (Co-presentation with ZEB).

Mette Bugge, Øyvind Skreiberg, Nils E. L. Haugen, Per Carlsson, Morten Seljeskog (2015). Predicting NOx emissions from wood stoves using detailed chemistry and computational fluid dynamics. Energy Procedia 75:1740-1745.

Øyvind Skreiberg, Morten Seljeskog, Laurent Georges (2015). The process of batch combustion of logs in wood stoves - Transient modelling for generation of input to CFD modelling of stoves and thermal comfort simulations. Chemical Engineering Transactions 43:433-438. (Co-publication with ZEB).

Laurent Georges, Øyvind Skreiberg (2014). Simulation of the Indoor Thermal Environment in Passive Houses heated using Wood Stoves: comparison between thermal dynamic simulations and CFD. 1st International Workshop on CFD and Biomass Thermochemical Conversion, 30th September 2014, DBFZ, Leipzig, Germany, pp. 57-61. (Co-publication with ZEB).

Laurent Georges, Øyvind Skreiberg, Vojislav Novakovic (2014). On the proper integration of wood stoves in passive houses under cold climates. Energy and Buildings 72:87-95. (Co-publication with ZEB).

Laurent Georges, Øyvind Skreiberg, Vojislav Novakovic (2013). On the proper integration of wood stoves in passive houses: Investigation using detailed dynamic simulations. Energy and Buildings 59:203-213. (Co-publication with ZEB).

Other news

IEA Task 32 Biomass Combustion and Co-firing

The first IEA Bioenergy Task 32 meeting of the year was arranged in May in Copenhagen, Denmark, in connection with the EUBCE 2018 conference. The meeting was combined with a field trip to the Amagerværket CHP plant.

2018 is the last year of the current triennium, and plans for activities in the next triennium (2019-2021) have been made, yet to be finalized.

The second Task 32 meeting was arranged in San Francisco in November in connection with the IEA Bioenergy end of triennium conference. There the proposed activities for the next triennium were further discussed, and based on this the final plans for the next triennium will made.

However, there will be significant focus on small-scale biomass combustion, including wood stoves.

In the current triennium, the deliverables connected to wood stoves are:

- Aerosols from biomass combustion
- Particle emission measurement techniques
- Consequences of real life operation on stove performance
- Workshop on Biomass Combustion Generated Nanoparticles
- Workshop on New Emission Measurement Methods

For information about IEA Bioenergy Task 32 activities, see the webpage and newsletters, and for IEA Bioenergy news, see this newsletter. Øyvind Skreiberg from SINTEF Energy Research is the Norwegian participant in IEA Bioenergy Task 32.

EERA Bioenergy – SP5 Stationary Bioenergy

The effort this year has been focused on revising the SP focus and the description of work, and this work is now soon finalized. A Strategic Research and Innovation Agenda (SRIA) has been made for the whole EERA Bioenergy, to be finalized this year. For more info on EERA Bioenergy, visit the brand new website, and see the newsletters. Berta Matas Güell from SINTEF Energy Research is leading SP5 Stationary Bioenergy in EERA Bioenergy.

RHC technology platform

The activity level of the RHC platform picked up after a period where new financing solutions were sought and the originally planned strategy documents had been delivered. The "new" European Technology and **Innovation** Platform on Renewable Heating & Cooling (RHC-ETIP) brings together stakeholders from the biomass, geothermal and solar thermal sector - including related industries such as District Heating and Cooling, Thermal Energy Storage, Hybrid Systems and Heat Pumps - to define a common Research, Development and Innovation strategy for increasing the use of renewable energy technologies for heating and cooling.

Previously concrete work has been carried out by the Biomass Panel in the RHC-ETIP connected to giving input to the SET-plan issues paper on renewable fuels and bioenergy, as well as work connected to the Implementation of the biomass technology roadmap of the Biomass Panel. The aim of the latter was to update the progress in R&I priorities identified by the Biomass technology roadmap. This work continues through different efforts. Øyvind Skreiberg from SINTEF Energy Research is a member of the Biomass Panel Steering Committee and has been the leader of Issue group 2: Residential/small scale heating devices and building integration.

For the next three years there will be a special focus on work to be carried out in horizontal working groups (HWG) that will focus on contributing to 1) vision, 2) research and innovation priorities and 3) deployment and innovation strategy documents. Øyvind Skreiberg will chair the HWG 100% Renewable Buildings, where a large number of members from the different RHC-ETIP panels already have expressed their interest in contributing to the HWG. Other working groups have been established on 100% Renewable Districts, 100% Renewable Cities and 100% Renewable Industry.

As a continuation of the SET-plan work, workgroups were established to provide specific input to the SET-plan work, e.g. Action 5 Energy Efficiency in Buildings with the sub-action 5.2 Heating and Cooling Technologies for Buildings and Action 8 Renewable Fuels and Bioenergy. Two meetings connected to Action 5 have been arranged in 2018 to provide input to this implementation plan. The work has now been finalized and an endorsed implementation plan is now ready. Øyvind Skreiberg has been involved in the Action 5 work, representing the Biomass Panel. For Action 8, an endorsed implementation plan has now been ready for a while.

See the RHC-ETIP newsletters for other news.

Links (click on the links or logos to get there)

StableWood
SKOG22
Energi21
Renewable Heating and Cooling technology platform
EERA Bioenergy
IEA Task32 Biomass Combustion and Cofiring