Newsletter 2-2014

StableWood

New solutions and technologies for heating of buildings with low heating demand:
Stable heat release and distribution from batch combustion of wood

www.sintef.no/StableWood

The StableWood project (2011-2014) has unfortunately come to an end as we approach the eve of 2014. In the final newsletter we are proud to present, although briefly, what the project has managed to achieve since its start in 2011, as well as recommendations and further work.

What has been achieved?

State-of-the-art and initial evaluations

Initially, studies were carried out to establish the state-of-the-art related especially to aspects that in the end are connected to emissions, efficiencies and the transient (a function of time) heat release from combustion of wood logs in wood stoves. Additionally, principles and methods to ensure the thermal comfort of the user when relying on wood stoves as the primary space heating source in modern types of buildings were investigated.

Wood stoves for modern energy efficient buildings as low-energy and passive houses will benefit from a combination of improvements that satisfies the user's and building's need in the optimum way. Specifically, fuel properties and their influence on the batch combustion process, choice and use of wood stove materials and their thermal properties, passive and active heat distribution methods, as well as room and building integration options were investigated.

Research methods

Experimental activities

Experimental activities have been carried out to establish the performance of current state-of-the-art technologies and to further improve upon these, as well as investigate aspects connected to the operation of wood stoves in low-energy and passive houses, regarding both thermal comfort and indoor air quality.

Modelling and simulations

Combining the traditional experimentally based development with modelling for an improved understanding of the special wood log batch combustion process gives the possibility to accelerate the development speed in a cost-efficient manner. Therefore, StableWood has also had a focus on modelling of the wood log batch combustion process and its transient heat production and subsequent heat release to a room, and through that additionally contributing to the understanding of this special combustion process and how to control it in the best possible way. This provides guidelines for the industry in their efforts to produce improved wood stoves as well as how to operate them in an optimum (environmental, energetic, heat comfort) way.

Feasibility studies

Feasibility studies have been an integrated part of the work carried out in StableWood with respect to evaluating the feasibility of using phase change material (PCM), different material configurations, and applying different passive and active heat distribution solutions, as well as considering constraints imposed by building regulations. In the end both technical and economic feasibility is necessary.

Combustion performance of state-of-the-art wood stoves

During the last two decades, the combustion performance of wood stoves has been improved significantly, leading to substantially reduced emissions due to incomplete combustion and also improved thermal efficiency. This continuous development has primarily been experimentally based. Combining experiments with modelling in the effort of designing the downscaled wood stoves of the future and their stable operating conditions has a great potential.

StableWood
- a Knowledge-building Project with User Involvement (KMB) co-funded by the Norwegian Research Council in the RENERGI-programme.
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Indoor air quality

In cooperation with a Danish research group, the indoor air quality (IAQ) performance of different wood log heating appliances installed in different low-energy and passive houses in Denmark and Norway have been investigated. Emissions into a room from the operation of a wood stove will to some degree happen, especially in a startup-phase and when the stove is refilled. The goal is to minimize these emissions to ensure an optimum IAQ. Parameters of importance are the wood stove design, proper selection/sizing and installation of the wood stove, and the operator of the wood stove.

Test standards for wood stoves

During the course of the StableWood project SINTEF Energy Research has as part of a continuous activity connected to standardization of approval tests for wood stoves participated in international standardization work as wells a in the development and testing of measurements methods to be introduced in updated standards. A main focus from the Norwegian side is the preservation also in future standards of testing the part load performance.

Transient conversion of wood logs

Modelling has been carried out with respect to the transient thermal decomposition of a single wood log and a batch of wood logs, as well as the transient combustion of a batch of wood logs. In such a modelling approach it is essential to establish with sufficient reliability the sub-models necessary (drying, volatiles release and char oxidation/gasification) to describe the thermal decomposition and the combustion process at the various relevant operating conditions. Modelling of a wood log, which is a very thermally thick particle (with large internal gradients, e.g. temperature) is challenging, and modelling of a batch of wood logs even more so. However, this is important work in the development of future's cost efficient modelling tools for optimal design and operation of wood stoves.

Heat transfer and storage in composite walls

The heat released from the transient combustion process, the heat production profile, will to a large extent be transferred through the wood stove walls, giving a heat release profile to the room. Depending on the walls' properties, this will be a time-delayed heat release profile compared to the heat production profile. As the heat release profile in the end heavily influences the thermal comfort in a building, it becomes essential to investigate methods to both dampen the typical heat production peak effect and prolong the heat release time. In StableWood a composite wall model was established, where the effect of a heat production profile on the heat release profile could be studied for different material configurations, including the use of PCM (Phase Change Materials). A PhD candidate has been financed by the StableWood project, with the specific task of investigating the applicability of using PCM to optimally control the heat release from wood stoves. This enables a very stable and significantly prolonged heat release, i.e. more controlled and reduced heat release.

Buildings integration simulations and experiments

In cooperation with FME Zero Emission Buildings, the effect of wood stoves in low-energy and passive houses on their thermal comfort was investigated through building integration simulations for various stove and building properties configurations, covering a wide range of stove-building configurations in different climate zones. The work clearly showed how wrong stove-building configurations would lead to unacceptable thermal comfort. However, it also showed that the proper configurations would lead to satisfactorily thermal comfort even in low-energy and passive houses.

CFD modelling

Computational fluid dynamics (CFD) simulations have the potential to incorporate all necessary physical and chemical processes going on in a wood stove during combustion of a batch of wood logs. In StableWood an initial work on stationary CFD modelling of wood stoves has been carried out, where a full detailed chemical kinetics mechanism has been used, as well as reduced, yet detailed, chemical kinetics mechanisms derived from the full mechanism. An appropriate reduction level gave similar results as the full mechanism, making it possible to significantly reduce the computational time without significantly sacrificing accuracy of the results. For NOx emissions, the CFD simulations showed significant reduction of fuel nitrogen, released from the fuel as NH3 and HCN, to molecular nitrogen, when applying staged air combustion. An optimum primary excess air ratio exists, giving the highest NOx emission reduction.

Recommendations

Based on the broad and comprehensive work carried out in StableWood the following recommendations can be given and conclusions can be drawn:

- Wood stoves for low-energy and passive houses needs to be downscaled (typically to 4 kW nominal effect and below) compared to today's typical wood stoves (of typically 8 kW nominal effect), without sacrificing environmental performance, but rather improving it.
- The StableWood project has generated a broad knowledge base and established guidelines and simplified tools to aid in the development of future's wood stoves for low-energy and passive houses.
- The negative effects of the unsteady and transient heat production profile in wood stoves can be reduced by applying the proper materials and material configurations to ensure a flattened heat release profile to the room.
- Also building architectonic measures should be sought to further improve the thermal comfort performance of wood stoves in low-energy and passive houses.

- Particle emission levels from wood stoves have continuously decreased after the introduction of a Norwegian test standard for approval testing of wood stoves. These levels will need to decrease further to improve the environmental performance of wood log combustion in stoves and conform to future's expected increasingly stricter environmental regulations.
- NOx emission reduction by staged air combustion can be applied also for wood stoves, however, the air distribution needs to be optimized to maximize the NOx reduction.
- An increased understanding of the transient combustion process in wood stoves should be sought, and should in the end be applied in a comprehensive CFD modelling tool for simulation of the combustion process, both transient and stationary simulations.
- A more concentrated effort is needed in the future on developing advanced modelling tools that together with targeted experimental work can be used effectively to design optimum environmental, energetic and user-friendly wood stoves that satisfies the thermal comfort demand of the user.
- In the end, wood stoves are not only a renewable space heating solution, but part of the Norwegian soul, and the flame picture and the crackling sound when the wood logs are burning are an important part of that. To be able to enjoy this and the heat comfort that wood stoves provide **a chimney is essential!**

StableWood in Gemini

StableWood was recently featured in an article ("Peiskos på sparebluss") in the online popular science magazine Gemini in connection with the finalizing of the project. See **http://gemini.no/2014/11/peiskos-pa-sparebluss/**

Further work

Today, 15 December 2014, the Research Council of Norway announced the list of new projects that will receive received funding within their ENERGIX program. The StableWood consortium submitted an application for a new competence building project within wood stoves this fall, which now are one of the projects that received funding. The project title is Clean and efficient wood stoves through improved batch combustion models and CFD modelling approaches (**WoodCFD**).

Final words

Big thanks to all the industrial partners for making the best out of the cooperation with SINTEF, as well as the Norwegian Research Council for making this possible.

Forskningsrådet

We'll be back!

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Dovre

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